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SDECAY: a Fortran code for the decays of the supersymmetric particles in the MSSM*

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Abstract

We present the Fortran code **SDECAY**, which calculates the decay widths and branching ratios of all the supersymmetric particles in the Minimal Supersymmetric Standard Model, including higher order effects. Besides the usual two-body decays of fermions and gauginos and the three-body decays of charginos, neutralinos and gluinos, we have also implemented the three-body decays of top squarks, and even the four-body decays of the top squark; the important loop-induced decay modes are also included. The QCD corrections to the two-body decays involving strongly interacting particles and the dominant components of the electroweak corrections to all decay modes are implemented.

*The code can be obtained at the url: <http://people.web.psi.ch/muehlleitner/SDECAY>

1. Introduction

The search for the new particles predicted by supersymmetric theories is a major goal of present and future colliders. A large theoretical effort has been devoted in the last two decades to determine the basic properties of these particles, as well as their decay modes and production mechanisms in collider experiments. Most of these studies have been performed in the framework of the Minimal Supersymmetric Standard Model (MSSM) [1–3], which has the minimal gauge structure, particle content and minimal interactions, and leads to a stable lightest supersymmetric particle (LSP).

As is well known, it is a very complicated task to deal in an exhaustive way with all the properties of these new particles and to make detailed and complete phenomenological analyses and comparisons with the outcome of or expectations from experiments. This is mainly due to the fact that, even in the MSSM, there are more than a hundred new parameters in the most general case, and even if one constrains the model to have a viable phenomenology, there are still over 20 free parameters left to cope with. This large number of inputs enters in the evaluation of the masses of $\mathcal{O}(30)$ supersymmetric (SUSY) particles and Higgs bosons as well as their complicated couplings, which involve several non-trivial aspects, such as the mixing between different states, the Majorana nature of some particles and, if the aim is to be quite precise, the higher order corrections. One then has to calculate, in the most accurate way, the rates for the many possible decay modes and production processes at the various possible machines.

Once SUSY particles are found, their properties are expected to be determined with an accuracy of a few per cent at the LHC [4] and a precision at the per cent level or below at future e^+e^- linear colliders [5]. To match this expected experimental accuracy, we need to calculate the mass spectra, the various couplings, the decay branching ratios and the production cross sections with a rather high precision, i.e. including the higher order effects. Leaving aside the production processes which are dealt with by Monte Carlo event generators, and for which the cross sections have been calculated at next-to-leading order (NLO) in some cases [6], one therefore needs to achieve the following goals:

- The physical (pole) masses and the various couplings [as well as the soft SUSY-breaking parameters which enter those] of the SUSY particles and the MSSM Higgs bosons need to be calculated very accurately. They must include all relevant features such as the masses of third-generation fermions, the mixing between the various states, and the radiative corrections when important. In constrained MSSMs two additional features need to be handled carefully: the renormalization group evolution (RGE) of parameters between the low-energy scale and the high-energy scale and the consistent implementation of radiative electroweak symmetry breaking (EWSB), i.e. the loop corrections to the effective scalar potential. There are several available RGE codes [7–10], which calculate the supersymmetric particle and Higgs boson masses as well as the soft SUSY-breaking parameters in the unconstrained and constrained MSSMs; they can be straightforwardly extended to allow for the calculation of the various and numerous couplings.

- All the possible two-body decay modes that can occur at the tree level [11] should be taken into account. These consist not only of decays of the inos¹ into fermion/sfermion pairs or sfermion decays into fermion/ino pairs, but also decays involving Higgs and gauge bosons in the final state. The QCD corrections, which are known to be rather large [12–14], need to be incorporated in the processes involving strongly interacting particles. In addition, some electroweak radiative corrections can be as large as the QCD corrections, and in principle, they should be taken into account. However, it is a tremendous task to calculate all these corrections, and they are available in the one-loop approximation [15] only for a very limited number of processes. Nevertheless, the bulk of these corrections, those stemming from the running of the gauge and Yukawa couplings and the running of some soft SUSY-breaking parameters, is available in the literature and can be incorporated with a minimum of effort.

- All possibly important higher order decay modes must be included. They consist of the three-body decay modes of the charginos, neutralinos and the gluino into lighter inos and two massless fermions [16, 17], which are known to be important, but also of the three-body decays of third-generation sfermions, which have been shown recently to be possibly important in some kinematical and parameter configurations [18, 19]. This is particularly the case for the top squark, when its mass is smaller than the lighter chargino mass and the sum of the masses of the lightest neutralino and the top quark. In fact, even the four-body decay mode of the top squark [20] has been shown to possibly compete with the flavour changing neutral current (FCNC) and loop-induced decay into a charm quark and the lightest neutralino [21], which also has to be included. Another set of loop-induced decay modes which might play a prominent role are the radiative decays of the next-to-lightest neutralino into the lightest neutralino and a photon [22, 23] and, to a lesser extent, the decay of the gluino into a gluon and the LSP [24].

The Fortran code **SDECAY**, which we present in this report, deals with the decays of SUSY particles in the framework of the MSSM, and includes the most important higher order effects. It uses the RGE program **SuSpect** [8] for the calculation of the mass spectrum and the soft SUSY-breaking parameters [but of course, the program can be easily linked to any other RGE code] and evaluates the various couplings of the SUSY particles and MSSM Higgs bosons. It calculates the decay widths and the branching ratios of all the two-body decay modes, including the QCD corrections to the processes involving squarks and gluinos and the dominant electroweak effects to all processes. It also calculates the loop-induced two-body decay channels, as well as all the possibly important higher order decay modes: the three-body decays of charginos, neutralinos, gluinos and third generation sfermions and the four-body decays of the top squark².

¹For simplicity, we will collectively call inos the charginos and neutralinos, and sometimes the gluinos.

²There are other programs which calculate the decay branching ratios of SUSY particles [7, 10, 25], and that also include some higher order effects. For instance, the loop decays and the three-body ino decays are included in **ISASUGRA**, **SPHENO** and **SUSYGEN**; the program **SPHENO** also deals with some three-body decays of the top squark. None of these programs includes the QCD corrections and the full set of

The program also calculates the decay widths and branching ratios of the heavy top quark. Besides the standard decay into a W boson and a bottom quark, the top quark decay widths into a charged Higgs boson and a bottom quark and into a top squark and a neutralino, are evaluated. The one-loop SUSY-QCD radiative corrections that are known [26] will be included in an upgraded version of the program.

Besides the **SuSpect** files needed for the evaluation of the spectrum, the code contains only one source file `sdecay.f`, written in Fortran77, and one input file, `sdecay.in`, from which any choice of approximation in the calculation is driven [including or not the higher order corrections and/or decays, the choice of the various scales, the order of perturbation at which some couplings are calculated, etc.]. All results for the total decay widths and branching ratios are given in the output file `sdecay.out`, either in a simple form or in the SUSY Les Houches Accord (SLHA) [27] form [this choice can be made in the input file]. The program is very user-friendly, self-contained and it can easily be linked with other codes or Monte Carlo event generators. It is rather fast and flexible, thus allowing scans of the parameter space with several possible options and choices for model assumptions and approximations.

The program **SDECAY** is of the same level of sophistication as the program **HDECAY** [28], which calculates the decay widths and the branching ratios of the [Standard Model and] MSSM Higgs bosons, including all relevant higher order effects. In fact, the three programs **SuSpect**, **HDECAY** and **SDECAY**, have many common features and subroutines, and are organized in a similar way. They provide a coherent, consistent and comprehensive description of the properties of the supersymmetric and Higgs particles in the MSSM, prior to the level of production which, as was mentioned previously, is the domain or “chasse gardée” of the Monte Carlo event generators. A light version, which combines these three programs, and which can be easily linked to any Monte Carlo generator, is under development and will appear quite soon [29].

The rest of this report is organized as follows. In the next section, we will summarize the main features of the MSSM that we will deal with, concerning the sparticle and Higgs boson masses and couplings, and the notation that we use in the program. In section 3, we discuss all the decay modes that are implemented and the way the higher order decays and the radiative corrections are included. In section 4, we discuss the main features and the structure of the program, briefly summarize how it works, and display the content of the input and output files. In section 5, a short conclusion will be given.

2. The implementation of the MSSM

The program **SDECAY** deals with the MSSM, i.e. with the basic assumptions of a:

- minimal gauge group, the Standard Model $SU(3)_C \times SU(2)_L \times U(1)_Y$ one,
- higher order decays of third-generation sfermions, though.

- minimal particle content: three generations of “chiral” sfermions $\tilde{f}_{L,R}^i$ [no right-handed sneutrinos] and two doublets of Higgs fields H_1 and H_2 ,
- minimal set of couplings imposed by R-parity conservation to enforce baryon and lepton number conservation in a simple way and which leads to a stable LSP,
- minimal set of soft SUSY-breaking parameters: gaugino mass terms M_i , scalar mass terms m_{H_i} and $m_{\tilde{f}_i}$, a bilinear term B and trilinear sfermion couplings A_i .

For the superpotential and the minimal set of soft SUSY-breaking, which give all the interactions and couplings, we follow the notations that can be found in the users manual of the program **SuSpect** [8], which we use for the determination of the SUSY particle and Higgs boson spectra. To have a viable phenomenology and a reduced number of free parameters, we thus also make the following three assumptions:

- (i) All the soft SUSY-breaking parameters are real and therefore no new source of CP-violation is generated, in addition to the one from the CKM matrix.
- (ii) The matrices for the sfermion masses and for the trilinear couplings are all diagonal, implying the absence of FCNCs at the tree level.
- (iii) The first and second sfermion generations are universal at low energy to cope with some severe experimental constraints [this is also motivated by the fact that we have neglected for simplicity all the masses of the first- and second-generation fermions which are small enough not to have any significant effect].

Making these three assumptions will lead to the so-called “phenomenological MSSM” (or pMSSM) discussed in [3], with 22 input parameters only:

$\tan \beta$: the ratio of the v evs of the two-Higgs doublet fields.

$m_{H_1}^2, m_{H_2}^2$: the Higgs mass parameters squared.

M_1, M_2, M_3 : the bino, wino and gluino mass parameters.

$m_{\tilde{q}}, m_{\tilde{u}_R}, m_{\tilde{d}_R}, m_{\tilde{l}}, m_{\tilde{e}_R}$: the first/second-generation sfermion mass parameters.

$m_{\tilde{Q}}, m_{\tilde{t}_R}, m_{\tilde{b}_R}, m_{\tilde{L}}, m_{\tilde{\tau}_R}$: the third-generation sfermion mass parameters.

A_u, A_d, A_e : the first/second-generation trilinear couplings.

A_t, A_b, A_τ : the third-generation trilinear couplings.

If one requires a proper electroweak symmetry breaking, the Higgs-higgsino (super-symmetric) mass parameter $|\mu|$ (up to a sign) and the soft SUSY-breaking bilinear Higgs term B are determined, given the above parameters [alternatively, one can trade the values of $m_{H_1}^2$ and $m_{H_2}^2$ with the “more physical” pseudoscalar Higgs boson mass M_A and parameter μ , a possibility provided by the program **SuSpect**, which deals with all the aspects of EWSB].

In constrained models, such as minimal Supergravity (mSUGRA) [30], the gauge-mediated SUSY breaking (GMSB) [31] and anomaly-mediated SUSY breaking (AMSB) [32] models, most of the 22 soft SUSY-breaking input parameters of the pMSSM listed above are derived from a set of universal boundary conditions at the high-energy scale [the

Grand Unification (GUT) scale for the mSUGRA and AMSB models and the messenger scale for the GMSB model]. In the mSUGRA case, for instance, the entire set of soft SUSY-breaking parameters [and thus the superparticle and Higgs spectrum] is determined by the values of only five free parameters: a common gaugino mass $m_{1/2} = M_i$, a universal scalar mass $m_0 = m_{\tilde{f}} = m_{H_i}$ and a universal trilinear coupling $A_0 = A_i$ at the GUT scale, the sign of the higgsino parameter μ and $\tan\beta$.

The low-energy soft SUSY-breaking parameters are then derived from the high-energy ones above through Renormalization Group Equations. [Note that the values of $|\mu|$ and M_A are obtained by requiring proper EWSB, which should be implemented, and the value of M_{GUT} is defined as the scale where the three gauge coupling constants of the Standard Model (SM) unify]. One then proceeds to calculate the pole masses of the Higgs bosons and all the supersymmetric particles, including the possible mixing between the current states and the radiative corrections [up to two loops in some cases] when they are important.

All these steps are performed by the program **SuSpect** and, for completeness, we reproduce in Fig. 1 the general algorithm that is used in the code [8]. This iterative algorithm includes the various important steps of the calculation: the choice of SM input parameters at low energy [the gauge coupling constants and the pole masses of the third-generation fermions], the calculation of the running couplings including radiative corrections in the modified Dimensional Reduction $\overline{\text{DR}}$ scheme [which preserves SUSY] and their RG running back and forth between the low and high scales, with the possibility of imposing the unification of the gauge couplings and the inclusion of SUSY thresholds in some cases, the RG evolution of the soft SUSY-breaking parameters from the high scale to the EWSB scale, the minimization of the one-loop effective potential and the determination of some important parameters, and finally the calculation of the particle masses including the diagonalization of the mass matrices and the radiative corrections.

To be more specific, we provide below a summary list of the higher order effects that have been included in the program:

- For the $\overline{\text{DR}}$ gauge and third-generation fermion Yukawa couplings, defined at the scale M_Z , the full set of standard and SUSY corrections has been implemented according to the approach of Pierce, Bagger, Matchev and Zhang (PBMZ) [33]. There are two exceptions: in the case of $\sin^2\theta_W$, the small SUSY particle contributions to the box diagrams have been omitted, and in the case of m_b and m_τ , only the QCD and the leading electroweak corrections at zero-momentum transfer have been incorporated [which, according to PBMZ, is a very good approximation]. In some cases, again according to the PBMZ approach, some important two-loop corrections have also been taken into account.

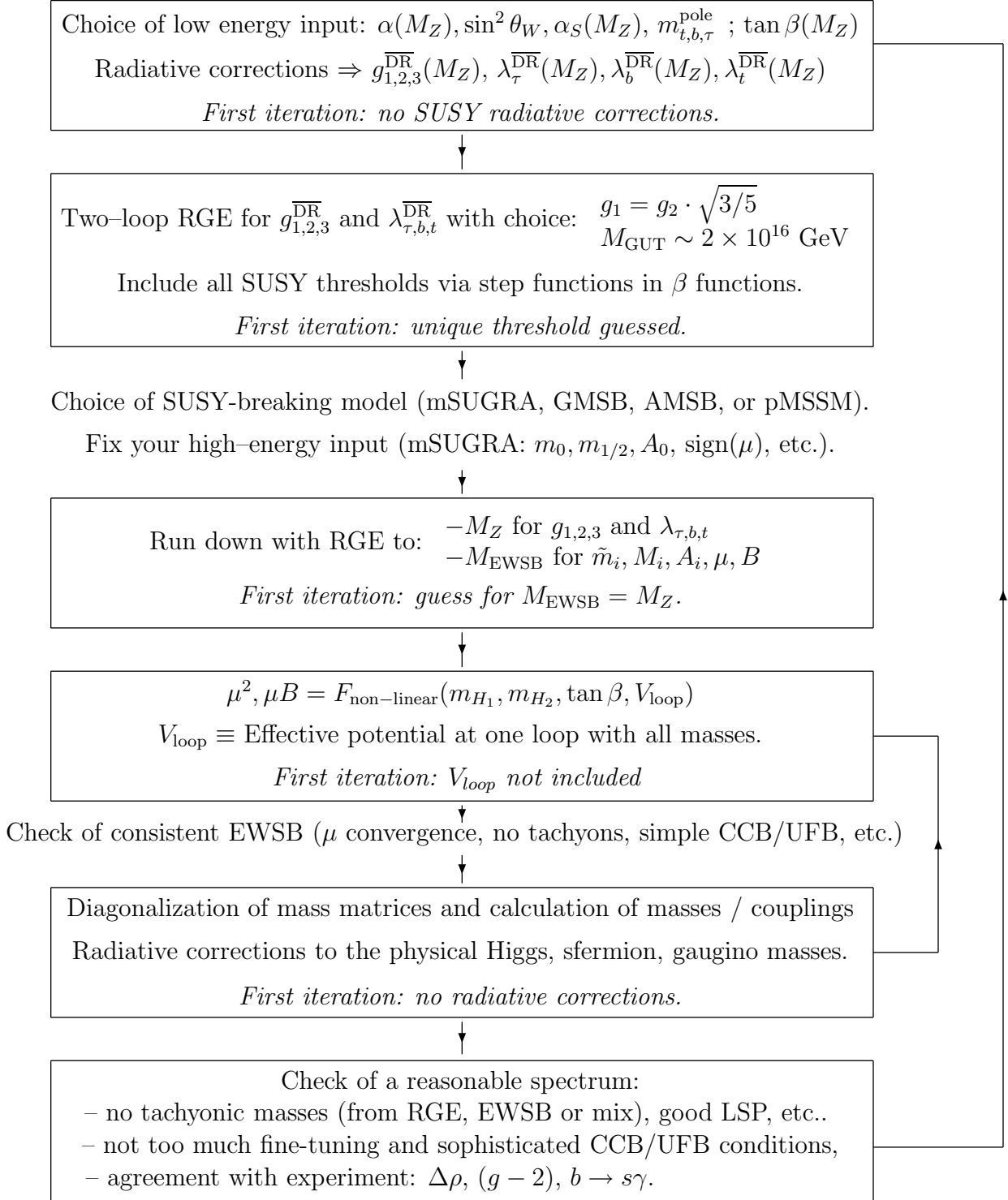


Figure 1: *Iterative algorithm for the calculation of the SUSY particle spectrum in SuSpect from the choice of input parameters (first step) to the check of the spectrum (last step). The EWSB “small” iteration on μ the RG/RC “long” iteration are performed until a satisfactory convergence is reached.*

- The RGEs have been used at the two-loop level for the gauge and Yukawa couplings, as well as for the three gaugino mass parameters M_1, M_2, M_3 and the two Higgs mass parameters m_{H_1}, m_{H_2} . For the other soft SUSY-breaking parameters [essentially the sfermion mass parameters $m_{\tilde{f}}$ and the trilinear couplings A_f], only the one-loop RGEs have been used. The GUT scale M_{GUT} can be either defined as the value at which the two gauge couplings g_1 and g_2 unify, or can be set by hand at $M_{\text{GUT}} \sim 2 \times 10^{16}$ GeV.

- The EWSB has been implemented through the tadpole method. The full one-loop standard and SUSY contributions to the tadpoles have been taken into account. The dominant two-loop corrections, those stemming from QCD and the third-generation fermion Yukawa couplings, have also been included. The EWSB scale has been chosen to be the geometric mean of the two top squark masses, $M_{\text{EWSB}} = (m_{\tilde{t}_1} m_{\tilde{t}_2})^{1/2}$.

- The soft SUSY-breaking parameters and the parameter μ that we obtain are all $\overline{\text{DR}}$ parameters defined at the scale M_{EWSB} . Using these parameters, the chargino and neutralino mass matrices are diagonalized with real matrices U/V and Z , respectively, to obtain the tree-level physical ino masses. The third-generation sfermion mass matrices are also diagonalized to obtain the tree-level sfermion masses, the mixing angles $\theta_{\tilde{t}}, \theta_{\tilde{b}}$ and $\theta_{\tilde{\tau}}$ being $\overline{\text{DR}}$ parameters defined at the scale M_{EWSB} .

- The radiative corrections to the sfermion masses are again included according to PBMZ [33], i.e. only the QCD corrections for the superpartners of light quarks [including the bottom squark] plus the full QCD and electroweak corrections to the two top squarks; the small electroweak radiative corrections to the slepton masses [which according to PBMZ are at the level of one per cent] have been neglected. The full one-loop QCD radiative corrections to the gluino mass are incorporated, while in the chargino/neutralino case, the radiative corrections to the masses are simply included in the gaugino and higgsino limits, which is a very good approximation according to PBMZ.

- The calculation of the masses of the MSSM Higgs bosons and the mixing angle α in the CP-even sector can be made using four routines that are available on the market: **Subhpole** [34], **HMSUSY** [35], **FeynHiggsFast** [36] and **Hmasses** [37]. In view of the approximations used in **SuSpect**, it is more appropriate to use the routine **Hmasses**, which has the same level of approximation, since it includes the full one-loop radiative corrections, and the dominant two-loop corrections at order $\alpha_s \lambda_f^2$ and λ_f^4 , λ_f being the Yukawa couplings of the third-generation fermions, $f = t, b$ and τ .

Using the gauge couplings, the third-generation fermion masses and the soft SUSY-breaking parameters discussed above, we then proceed in the program **SDECAY** to calculate all the couplings of the SUSY particles and the MSSM Higgs bosons. In most cases, we use the Feynman rules given by Haber et al. in Ref. [2]. These couplings are thus defined in the $\overline{\text{DR}}$ scheme and evaluated at the scale M_{EWSB} . Therefore, they already include some radiative corrections, and care should be taken when they are used in one-loop-corrected amplitudes to avoid double counting, as will be discussed later.

3. Decays of the SUSY particles

3.1 Two-body decays at the tree level

The main decay modes of sfermions will be into their partner fermions and neutralinos, as well as into their isospin partner fermions and charginos³

$$\tilde{f}_i \rightarrow f \chi_j . \quad (1)$$

In the case of squarks, when they are heavier than the gluino, they can also decay into gluino-quark final states

$$\tilde{q}_i \rightarrow q \tilde{g} . \quad (2)$$

If the mass splitting between two sfermions of the same generation is large enough, as can be the case of the third-generation (\tilde{t}, \tilde{b}) and $(\tilde{\nu}_\tau, \tilde{\tau})$ isodoublets, the heavier sfermion can decay into the lighter one plus a gauge boson $V = W, Z$ or a Higgs boson $\Phi = h, H, A, H^\pm$

$$\tilde{f}_i \rightarrow \tilde{f}'_j V , \quad (3)$$

$$\tilde{f}_i \rightarrow \tilde{f}'_j \Phi . \quad (4)$$

The heavier neutralinos and charginos will decay into the lighter chargino and neutralino states and gauge or Higgs bosons

$$\chi_i \rightarrow \chi_j V \quad (5)$$

$$\chi_i \rightarrow \chi_j \Phi \quad (6)$$

and, if enough phase space is available, into fermion-sfermion pairs

$$\chi_i \rightarrow f \tilde{f}_j . \quad (7)$$

For gluinos, when they are heavier than squarks, their only relevant decay channel will be into quark plus squark final states:

$$\tilde{g} \rightarrow q \tilde{q} . \quad (8)$$

In the case of the GMSB model, the lightest SUSY particle is the gravitino \tilde{G} . The next-to-lightest SUSY particle (NLSP) can be either the lightest neutralino or the lightest sfermion, in general the $\tilde{\tau}_1$ [in which case, the decay $\chi_1^0 \rightarrow \tilde{\ell} \ell$ is allowed kinematically]. If the NLSP is a slepton, its only allowed decay is into a lepton and a gravitino, $\tilde{\ell} \rightarrow \ell \tilde{G}$, with a branching ratio of 1. If the NLSP is the lightest neutralino, there are several possible decays, $\chi_1^0 \rightarrow \gamma \tilde{G}, Z \tilde{G}$ and $\tilde{G} \Phi$ with $\Phi = h, H, A$.

³Here and in the following, we collectively denote by χ_i the charginos and neutralinos, and we discard the distinction between the two isospin sfermion partners.

The program **SDECAY** calculates the partial widths and the branching ratios of all these decays, including all possible combinations. It first checks if the decay is phase-space-allowed and then uses the two-body simple formulae available in the literature; see for instance Refs. [17, 19]. The masses involved in the phase space are all pole masses [i.e., in the case of the SUSY and Higgs particles, the one-loop renormalized masses given by **SuSpect**]. The masses of the third-generation fermions [the only ones in the program that are assumed to be non-zero] are the on-shell masses when they enter the phase space but the running $\overline{\text{DR}}$ masses defined at the scale M_{EWSB} when they enter the various couplings. This is also the case of all the soft SUSY-breaking parameters and the third-generation sfermion mixing angles that enter the couplings. Nevertheless, we have left as an option the possibility for the QCD coupling constant and the b, t Yukawa couplings, to be evaluated at the scale of the decaying superparticle or any other scale. However, in this case, only the standard QCD corrections are included in the running, following the approach of Ref. [38].

3.2 QCD corrections to the two-body decays

The one-loop QCD corrections have been incorporated to the two-body decay processes involving (s)quarks or gluinos in the initial or final state; more specifically, they have been included in the following processes

$$\tilde{q}_i \rightarrow q\chi_j \quad (9)$$

$$\tilde{q}_i \rightarrow \tilde{q}_j\Phi \quad (10)$$

$$\tilde{q}_i \rightarrow q\tilde{g} \quad \text{and} \quad \tilde{g} \rightarrow \tilde{q}_i q . \quad (11)$$

We have used the formulae given in Refs. [12], [13] and [14] for, respectively, the processes of eqs. (9), (10) and (11). The corrections for the process $\chi_i \rightarrow \tilde{q}_i q$ that can be adapted from the ones of the reverse process, eq. (9), and the corrections to the decay $\tilde{q}_i \rightarrow \tilde{q}_j V$ will be implemented in the next version of the program. The Passarino-Veltman one-, two- and three-point functions for the loop amplitudes have been implemented using the formulae given in Ref. [39]. For the three-body phase-space integrals, when an additional gluon is emitted in the final state, we use the analytical formulae given in Refs. [12–14] and which involve at most Spence functions.

A few remarks are worth making at this stage:

(i) All the corrections have been incorporated in the $\overline{\text{DR}}$ scheme, while in the previous references some corrections were calculated in the $\overline{\text{MS}}$ scheme. In the latter case the differences between the two schemes have to be corrected by additional counterterms. The results for the physical observables of course will be the same in the two schemes up to the calculated order, as it should be.

(ii) All the masses of the particles involved in the processes, in particular those of the strongly interacting particles, which in principle need to be renormalized, are pole masses,

i.e. are defined on the mass shell. The self-energies of these particles are defined in such a way that the residues at the poles are unity.

(iii) Because the top and bottom quark masses and the stop and sbottom mixing angles [and thus the trilinear couplings A_t and A_b] that are obtained using the program **SuSpect**, already include some one-loop contributions, some care has to be taken when dealing with the renormalization of these parameters and their one-loop counterterms to avoid double counting [in fact only the divergent pieces have to be included].

(iv) In the case of decays involving gluinos, which are strong interaction decays already at the tree level, a special treatment is needed for $\alpha_s(\mu_R)$, where μ_R is the renormalization scale. The heavy particles, top quarks, squarks and gluinos should be removed from the μ_R^2 evolution of α_s and decoupled for momenta smaller than their masses.

Finally, as mentioned previously, the bulk of the electroweak radiative corrections which is due to the running of the gauge and third-generation fermion Yukawa couplings, is already taken into account since these parameters, when appearing in the amplitudes, have been evaluated at the EWSB scale. The remaining corrections [including photon emission in the initial or final state] are of the order of the electromagnetic coupling constant and should lead to corrections at the level of a few per cent only. These corrections can thus be safely neglected in a first stage.

3.3 Loop-induced decays

a) Radiative decays of the next-to-lightest neutralino (and gluino)

If the mass splitting between the next-to-lightest neutralino and the lightest neutralino is very small, the two-body neutralino decays discussed previously are not allowed kinematically; the virtuality of the exchanged particles in the possible three-body decay modes [to be discussed later] is so large that the loop-induced decays of at least χ_2^0 into the LSP χ_1^0 and a photon [22, 23]

$$\chi_2^0 \rightarrow \chi_1^0 \gamma \quad (12)$$

might be relevant. This decay is induced by triangle diagrams involving the contribution of virtual charginos together with W and charged Higgs bosons, and contributions with charged sfermion/fermion loops. It is of $\mathcal{O}(\alpha^3)$ in the electroweak coupling, but can have a sizeable branching ratio [with respect to the three-body decays] in some areas of the MSSM parameter space and in some corners of the phase space.

For the full analytical formulae of the decay amplitudes, we use the ones that were given in Ref. [22], which are closer to our Lagrangian convention and leads to an easier implementation in our program. All diagrams and contributions have been taken into account.

For completeness, and although this mode is never very important in the MSSM, we have extended the previous calculation to the case where the gluino decays into a gluon

and the lightest neutralino [24]

$$\tilde{g} \rightarrow g\chi_1^0, \quad (13)$$

which is mediated by only a subset of the diagrams involved in the previous decay mode [that is, only the squark-quark loop contributions].

b) Loop-induced decay of the lightest top squark

The heaviness of the top quark leads to distinct phenomenological features for the decays of its scalar partners. Indeed, while the other squarks can decay directly into (almost) massless quarks and the lightest neutralino χ_1^0 , which is always kinematically accessible, since in general, in the MSSM the neutralino χ_1^0 is assumed to be the LSP, the decay channels $\tilde{t}_i \rightarrow t\chi_1^0$ are kinematically closed for $m_{\tilde{t}_i} \leq m_t + m_{\chi_1^0}$. If, in addition, $m_{\tilde{t}_i} \leq m_b + m_{\chi_1^+}$, the decay mode into a chargino and a b quark, $\tilde{t}_i \rightarrow b\chi_1^+$, is not accessible and the only two-body decay channel that would be allowed is the loop-induced and FCNC decay [21]:

$$\tilde{t}_i \rightarrow c\chi_1^0 \quad (14)$$

This mode is mediated by one-loop diagrams: vertex diagrams as well as squark and quark self-energy diagrams [where bottom squarks, charginos, charged W and Higgs bosons are running in the loops]. The flavour transition $b \rightarrow c$ occurs through the charged currents. Adding the various contributions, a divergence is left out, which must be subtracted by adding a counterterm to the scalar self-mass diagrams. When working in mSUGRA-type models, where the squark masses are unified at the GUT scale, the divergence is subtracted using a soft counterterm at Λ_{GUT} , generating a large residual logarithm $\log(\Lambda_{\text{GUT}}^2/M_W^2) \sim 65$ in the amplitude. This logarithm gives the leading contribution to the $\tilde{t}_1 \rightarrow c\chi_1^0$ amplitude and makes the decay width rather large, although it is suppressed by the CKM matrix element $V_{cb} \sim 0.05$ and the (running) b quark mass squared $m_b^2 \sim (3 \text{ GeV})^2$. It is this approach that we have implemented in the program **SDECAY** and we have used the approximate formulae of Ref. [21] [the exact expressions of the loop amplitudes are not yet available].

However, there are scenarios in which the decay rate $\Gamma(\tilde{t}_1 \rightarrow c\chi_1^0)$ can be rather small: (i) First, the large logarithm $\log(\Lambda_{\text{GUT}}^2/M_W^2) \sim 65$ appears only because the choice of the renormalization condition is made at Λ_{GUT} , but in a general MSSM, where the squark masses are not unified at some very high scale, one could chose a low-energy counterterm; in this case no large logarithm would appear. (ii) If the lightest top squark is a pure right-handed state [as favoured by the constraints from high-precision electroweak data], the amplitude involves only one component, which can be made small by choosing small values of the trilinear coupling A_b and/or large values of the (common) SUSY-breaking scalar mass \tilde{m}_q . (iii) Even in the presence of stop mixing, for a given choice of MSSM parameters, large cancellations can occur between the various terms in the loop amplitude; in addition, the $t\text{--}\tilde{t}_1\text{--}\chi_1^0$ coupling, which enters as a global factor, can be very tiny.

Thus, the decay rate $\Gamma(\tilde{t}_1 \rightarrow c\chi_1^0)$ might be very small, opening the possibility for the three-body and even four-body decay modes, which will be discussed now, to dominate.

3.4 Multibody decay modes

If the tree-level two-body decay modes discussed previously are kinematically closed, i.e. equal to zero, multibody final state channels [as well as the loop decays which have been discussed previously] will be the dominant decays and should be considered. There are three varieties of such decays with which the program **SDECAY** deals, and which will be discussed below. In all cases, we make a clear separation between the two-body and multibody decays: that is, in the higher order decay modes, we do not include the total decay widths of the virtually exchanged (s)particles in their respective propagators, so as to make smooth transitions between the two-body and the multibody decay modes⁴.

a) Three-body decays of charginos, neutralinos and gluinos

When the two-body channels of the charginos and neutralinos given in eqs. (5–7) are kinematically closed, the particles can decay into three-body final states involving a lighter ino and two massless fermions:

$$\chi_i \rightarrow \chi_j f \bar{f} . \quad (15)$$

In the past, these decays have been discussed in particular for the lightest chargino and for the next-to-lightest neutralino, when decaying into the LSP neutralino and two fermions, $\chi_1^+ \rightarrow \chi_1^0 f \bar{f}'$ and $\chi_2^0 \rightarrow \chi_1^0 f \bar{f}$. In our case, we will not assume that the initial inos are χ_1^+ and χ_1^0 and the final neutralino is the LSP χ_1^0 , but any of the charginos χ_i^+ ($i = 1, 2$) and neutralinos χ_i^0 ($i = 1, \dots, 4$) to cover all situations and the possibility of cascade decays. These decays proceed through gauge boson exchange [$V = W$ and Z for χ_i^+ and χ_i^0 decays, respectively], Higgs boson exchange [$\Phi = H^+$ for χ_i^+ decays and $\Phi = H, h, A$ for χ_i^0 decays] and sfermion exchange in the t - and u -channels [the flavour is fixed by the sfermion-fermion and final neutralino vertex].

The gluino can also undergo three-body decays when the two-body decays of eq. (8) are kinematically forbidden:

$$\tilde{g} \rightarrow \chi q \bar{q} , \quad (16)$$

and only the channels with t - and u -channel squark exchange will be present in this case; the partial widths can be straightforwardly derived from those of the neutralino decays,

⁴This aspect leads to very complicated technical problems and numerical instabilities. Indeed, once the total decay widths of the virtual particles are included, the phase-space integrals cannot be made analytically and one has to resort to a numerical integration which gives less precise results and heavily slows down the program. In addition, there are issues of gauge invariance that are not yet settled in this case, and which we did not want to address at the moment.

with the appropriate change of the couplings and the QCD factors. We also implemented the decay

$$\tilde{g} \rightarrow \tilde{t}_1 \bar{b} W^- \quad (17)$$

which can be important in regions of the parameter space where it is kinematically allowed [40]. Furthermore the decay [41]

$$\tilde{g} \rightarrow \tilde{t}_1 \bar{b} H^- \quad (18)$$

has been taken into account.

In fact, the heavier charginos and neutralinos can also decay [in particular, in models with non-universal gaugino masses at high scale] into gluinos and quark-antiquark pairs

$$\chi_i \rightarrow \tilde{g} q \bar{q} \ , \quad (19)$$

and the amplitude can be adapted from the one of the reverse process eq. (16) discussed above.

The program **SDECAY** calculates the partial widths and branching ratios of all these three-body decay channels, taking into account all the possible contributions of the virtual particles. The radiatively corrected Yukawa couplings of third-generation fermions, the mixing pattern for their sfermion partners and the masses of the sparticles and gauge/Higgs bosons involved in the processes are taken into account. In fact, even the masses of the fermion final states have been taken into account, since finite fermion masses are needed in some cases⁵. We have used the analytical formulae of Ref. [17] for the matrix elements squared and integrated numerically over the three-body phase space.

b) Three-body decays of third-generation sfermions

For relatively heavier top squarks, when their masses are larger than the mass of the χ_1^0 neutralino and the mass of the W boson, the H^\pm boson and/or the sfermion \tilde{f}^* , there will be the possibility of the three-body decay modes of the \tilde{t}_1 . These modes have been discussed in Refs. [18, 19]. When kinematically possible, some of these channels can dominate over the loop-induced $\tilde{t}_i \rightarrow c \chi_1^0$ mode in rather large areas of the MSSM parameter space.

For $m_{\tilde{t}_1} > M_{W(H^\pm)} + m_{\chi_1^0}$, the three-body decay channels into W or charged Higgs bosons, a bottom quark and the LSP neutralino,

$$\tilde{t}_i \rightarrow b W^+ \chi_1^0 \ , \ b H^+ \chi_1^0 \quad (20)$$

⁵The approximation of zero mass is rather good for all light fermion final states, except for b -quarks and τ -leptons when χ_2^0 and χ_1^+ have masses close to the χ_1^0 mass; the zero-mass approximation would be very bad for top quark final states. Nevertheless, in mSUGRA-type models, if the three-body decays $\chi_2^0 \rightarrow \chi_1^0 t \bar{t}$ and $\chi_1^+ \rightarrow \chi_1^0 t \bar{b}$ are kinematically allowed, they will not play a major role, since the charginos and neutralinos will have enough phase space to decay first into the two-body channels $\chi_2^0 \rightarrow \chi_1^0 Z$, $\chi_1^0 h$ [and possibly $\chi_1^0 H$ and $\chi_1^0 A$] and $\chi_1^+ \rightarrow \chi_1^0 W$ [and possibly $\chi_1^0 H^+$], which will be largely dominating.

can be accessible and have been shown to be [at least for the one with W boson final states] often dominant in the case where $m_{\tilde{t}_1} \leq m_t + m_{\chi_1^0}$ and $m_b + m_{\chi_1^+}$. In addition, if sleptons are lighter than squarks [as is often the case in models with a common scalar mass at the GUT scale, such as the mSUGRA model] the modes

$$\tilde{t}_i \rightarrow bl^+\tilde{\nu}_l \text{ and/or } b\tilde{l}^+\nu_l \quad (21)$$

become possible. In the case of the lightest top squarks, they can be largely dominating over the loop-induced $c\chi_1^0$ mode.

In fact, these three-body decay modes are important not only for the lightest top squark, but also for the heavier one. In addition, there is another possibility which is the decay of the top squarks into a fermion-antifermion pair and the lightest \tilde{b} state [which can become the lightest scalar quark in the case where $\tan\beta$ is very large], which is mediated by the virtual exchange of W and H^+ bosons:

$$\tilde{t}_i \rightarrow \tilde{b}_1 f \bar{f}' . \quad (22)$$

For the heavier top squark \tilde{t}_2 , another possibility would be the three-body decay into the lightest top squark and a fermion pair [with $f \neq b$] through the exchange of the Z and the MSSM neutral Higgs bosons [the CP-even h, H and the CP-odd A bosons],

$$\tilde{t}_2 \rightarrow \tilde{t}_1 f \bar{f} . \quad (23)$$

These modes apply also for the charged decays of heavier bottom squarks into top squarks (and vice versa) which, as previously, occur through W and H^+ boson exchanges

$$\tilde{q}_2 \rightarrow \tilde{q}'_j f \bar{f}' . \quad (24)$$

[If the mass splitting between the initial and final scalar eigenstates is large enough, the gauge and Higgs bosons become real, and we have the two-body decays into gauge and Higgs bosons which have been discussed previously.]

For $b\bar{b}$ final states, one needs to include, in the case of $\tilde{t}_2 \rightarrow \tilde{t}_1 b\bar{b}$, the contributions of the exchange of the two charginos states $\chi_{1,2}^+$. This is also the case of the decay mode $\tilde{b}_2 \rightarrow \tilde{b}_1 b\bar{b}$, where one has, in addition, the virtual exchange of neutralinos and gluinos, which have to be taken into account. The latter process is a generalization [since the mixing pattern is more complicated] of the decay modes of first- and second-generation squarks into light scalar bottoms [19], and would be in competition with at least the two-body mode $\tilde{b}_2 \rightarrow b\chi_1^0$. The latter channel is always open since χ_1^0 is the LSP, but the $b\tilde{b}_2\chi_1^0$ coupling can be small, leaving the possibility to the three-body mode to occur at a sizeable rate.

SDECAY evaluates all the three-body decay modes of the top squarks discussed above, when the corresponding two-body decay channels are kinematically closed. In all cases, the analytical expressions for the Dalitz plot densities in terms of the energies of the

final fermions [19], which take account of all contributing channels, mixing and masses [including non-zero third-generation fermion masses], are integrated numerically. As in the case of the inos, the total decay widths of the exchanged particles are not included in the propagators of the virtual particles. The three-body decays of the bottom squarks will be included in the upgraded version of **SDECAY**.

c) The four-body decay of the top squark

If the previous three-body decay modes of the top squarks are kinematically not accessible, the main \tilde{t}_1 decay channel is then expected to be the loop-induced and flavor-changing decay into a charm quark and the LSP, $\tilde{t}_1 \rightarrow c\chi_1^0$. However, there is another decay mode that is possible in the MSSM, even if \tilde{t}_1 is the next-to-lightest SUSY particle [provided that $m_{\tilde{t}_1} > m_{\chi_1^0} + m_b$]: the four-body decay into a b -quark, the LSP and two massless fermions [20]:

$$\tilde{t}_1 \rightarrow b\chi_1^0 f\bar{f}' . \quad (25)$$

This mode is of the same order of perturbation theory as the decay $\tilde{t}_1 \rightarrow c\chi_1^0$, i.e. $\mathcal{O}(\alpha^3)$; in principle, it can therefore compete with the latter channel.

The four-body decay mode proceeds through several diagrams: there are first the W -boson exchange diagrams with virtual t, \tilde{b} and $\chi_{1,2}^\pm$ states, a similar set of diagrams is obtained by replacing the W -boson by the H^\pm -boson and a third type of diagrams consist of up and down type slepton and first/second-generation squark exchanges. The decay rate has been calculated in Ref. [20] taking into account all diagrams and interferences. The various contributions can be summarized as:

i) Because in the MSSM, H^\pm has a mass larger than M_W and has tiny Yukawa couplings to light fermions, it does not give rise to large contributions. The squark exchange diagrams give also small contributions since squarks are expected to be much heavier than the \tilde{t}_1 state. The contribution of the diagram with an exchanged t -quark is only important if the stop mass is of the order of $m_t + m_{\chi_1^0} \gtrsim \mathcal{O}(250 \text{ GeV})$.

ii) In contrast to squarks, slepton [and especially $\tilde{\nu}$] exchange diagrams might give substantial contributions, since \tilde{l} masses of $\mathcal{O}(100 \text{ GeV})$ are still experimentally allowed [42]. In fact, when the difference between $m_{\tilde{t}_1}$ and $m_{\chi_1^+}$ and $m_{\tilde{l}}$ is not large, this diagram will give the dominant contribution to the four-body decay mode.

iii) The most significant contributions to the four-body decay mode will come in general from the diagram in which the lightest chargino χ_1^+ and the W boson are exchanged, when the virtuality of the chargino is not too large. In particular, for an exchanged χ_1^+ with a mass not much larger than 100 GeV, the decay width can be substantial even for top squark masses of the order of 100 GeV.

Thus, a good approximation [especially for a light top squark $m_{\tilde{t}_1} \sim \mathcal{O}(100 \text{ GeV})$] is to take into account only the top quark, the lightest chargino and the slepton exchange diagrams. All the other contributions, in particular the H^\pm contribution, can be safely

neglected in general. This is the approach that we choose in **SDECAY**: we include all the contributions and the interference effects, except for the small H^\pm contribution which is very lengthy and time consuming to evaluate. The four-body phase-space integrals are evaluated using the program **Rambo**.

3.5 Decays of the top quark

The decays of the heavy top quark in the MSSM that have also been included in the program consist of the standard decay into a W boson and a bottom quark,

$$t \rightarrow bW^+ \quad (26)$$

but also, if allowed by phase space, of the decays into a bottom quark and an H^\pm boson and into a lighter top squark and a neutralino

$$t \rightarrow bH^+ \text{ and } \tilde{t}_1\chi_1^0 \quad (27)$$

In addition, the one-loop QCD corrections [26] will be included in the next version of the program.

4. Running SDECAY

4.1 Basic facts about SDECAY

Besides the files of the program **SuSpect**, i.e. the input file **suspect2.in** [where one can select the model to be investigated, the accuracy of the spectrum algorithm, the input data (SM fermion masses and gauge couplings) as well as SUSY and soft SUSY-breaking parameters] and the main Fortran routine **suspect2.f** [where some internally documented changes have been performed for a fully consistent calculation, and the calling routine **suspect2.call.f** is not needed], where the calculation of the spectrum is performed and which needs the routines **subh_hdec.f**, **feynhiggs.f**, **hmsusy.f** and **Hmasses** for the calculation of the Higgs boson masses, the program **SDECAY** is composed of three files:

1) The input file **sdecay.in**: in this file, one can choose the accuracy of the algorithm and make the choice of the various options: whether QCD corrections and multibody or loop decays are included, which scales are used for the couplings, the number of loops in their running and if top and GMSB decays are to be evaluated or not.

2) The main routine **sdecay.f** where the couplings of the SUSY particles and Higgs bosons are evaluated and the decay branching ratios and total widths are calculated. This routine is self-contained and includes all the necessary files for the calculation.

3) The output file **sdecay.out**: this file is generated at each run of the program and gives the results for the output branching ratios and total decay widths. Two formats are possible for this file: either the Higgs and SUSY particles are denoted in a simple and transparent form, or the PDG notation is used. In addition, the masses of the SUSY and

Higgs particles, the mixing matrices and the gauge and third-generation couplings at the EWSB or a chosen scale are given. [An additional output `suspect2.out` is also generated for the spectrum and also includes the soft SUSY-breaking terms].

The routine `sdecay.f` consists of about 30.000 lines of code and takes about 1 Mo of memory, while the input file only has a few dozen lines (most of them comments). The accompanying routines for the calculation of the sparticle and Higgs masses, which are provided separately, have in total a comparable size. The complete executable file takes about 2.5 Mo of disk space. The running time for a typical model point, for instance the mSUGRA point discussed below, is a few seconds on a PC with a 1 GHz processor.

The Fortran files have to be compiled altogether and, running for instance on a PC, the compilation and link commands are [they are provided in a makefile]:

```
OBJS = suspect2.o subh_hdec.o feynhiggs.o hmsusy.o sdecay.o
FC=f77
.f.o:
    $(FC) -c $.f
sdecay: $(OBJS)
    $(FC) $(OBJS) -o run
```

Thus, the program SDECAY has the following structure:

- It reads all the inputs in the files `suspect2.in` and `sdecay.in`.
- It calculates the sparticle and Higgs boson masses as well as all the soft SUSY-breaking parameters using the program `SuSpect`.
- It calls the subroutine `common_ini` where all parameters necessary for the calculation of the couplings and decay widths are set.
- It calls the subroutine `couplings` where all couplings necessary for the calculation of the decay widths are evaluated.
- It calls the subroutines for the two-body decays (2), the three-body decays (3) and loop decays (1) and for the stop four-body decay (4) calculation of the total widths and branching ratios of the respective decaying particle:

chargino decays:	subroutines: char2bod (2), xintegchipm (3)
neutralino decays:	subroutines: neut2bod (2), xintegneut (3), neutraddecay (1)
gluino decays:	subroutines: glui2bod (2), xinteggio (3), gluiraddecay (1)
stop decays:	subroutine : stop2bod (2)
sdown decays:	subroutine : sdown2bod (2)
stop decays:	subroutines: st2bod (2), xintegstop (3), hikasakob1 (1), st4bod (4)

```

sbottom decays:      subroutine : sb2bod (2)
selectron decays:    subroutine : sel2bod (2)
sneutrino_el decays: subroutine : snel2bod (2)
stau decays:         subroutine : stau2bod (2)
sneutrino_tau decays: subroutine : sntau2bod (2)

```

The routines call several help functions and subroutines for the loop decays, the QCD corrections, and some matrix elements for the multibody decays. They can be found at the end of the program with some comments specifying their purposes and their main features.

- It writes in the output file `sdecay.out` where you can choose two versions: the output à la Les Houches Accord or one that is easier to read.

In the next subsections, we will exhibit the input and output files, taking the example of an mSUGRA benchmark point from the Snowmass Points and Slopes [43], the so-called SPS1a point, with the inputs at the high scale:

$$m_0 = 100 \text{ GeV} , \ m_{1/2} = 250 \text{ GeV} , \ A_0 = -100 , \ \tan\beta = 10 , \ \mu > 0 .$$

The input and output files are self-explanatory and will not be commented further.

4.2 The input file

SDECAY INPUT FILE

```

* Choice of the output, Les Houches Accord (1) or simple (0):
1

* Include (1) or not (0) the QCD corrections to the 2-body decay widths:
0

* Include (1) or not (0) the multi-body decays for inos and stops:
1

* Include (1) or not (0) the loop induced decays for the gluino,
  the neutralinos and stop1:
1

* Include (1) or not (0) the SUSY decays of the top quark:
1

* Include (1) or not (0) the possible decays of the NLSP in GMSB models:

```

```

    (ichoice(1) has to be set 11 in suspect2.in.)
0

* Scheme in which the running alphas and quark masses are calculated
  if the scale is not the scale of EWSB:
  (If QCD corrections are included, the DR_bar scheme has to be used.)
  0 (MS_bar scheme) and 1 (DR_bar scheme).
1

* Scale at which the scale dependent couplings are calculated:
  1: EWSB scale, 2: mass of the decaying sparticle, 3: user choice
1

* Scale of the scale dependent couplings if chosen by the user
  (in GeV):
100.D0

* Number of loops for the calculation of the running couplings
2

```

4.3 Output file according to SLHA

```

# SUSY Les Houches Accord - MSSM Spectrum + Decays
# SDECAY 1.0
# Authors: M.Muhlleitner, A.Djouadi and Y.Mambrini
# In case of problems please send an email to
# margarete.muehlleitner@psi.ch
# djouadi@lpm.univ-montp2.fr
# mambrini@delta.ft.uam.es
#
# If not stated otherwise all couplings and masses
# are given at the scale of the electroweak symmetry
# breaking Q= 0.46296529E+03
#
#
BLOCK MASS # Mass Spectrum
# PDG code      mass      particle
      25      1.14365068E+02  # h
      35      3.91956602E+02  # H
      36      3.92191912E+02  # A
      37      4.00353329E+02  # H+

```

1000001	5.69828109E+02	# ~d_L
2000001	5.43157826E+02	# ~d_R
1000002	5.64244153E+02	# ~u_L
2000002	5.44093303E+02	# ~u_R
1000003	5.69828109E+02	# ~s_L
2000003	5.43157826E+02	# ~s_R
1000004	5.64244153E+02	# ~c_L
2000004	5.44093303E+02	# ~c_R
1000005	5.16713072E+02	# ~b_1
2000005	5.44166483E+02	# ~b_2
1000006	4.00256829E+02	# ~t_1
2000006	5.80537860E+02	# ~t_2
1000011	2.03724637E+02	# ~e_L
2000011	1.45386789E+02	# ~e_R
1000012	1.87810224E+02	# ~nu_eL
1000013	2.03724637E+02	# ~mu_L
2000013	1.45386789E+02	# ~mu_R
1000014	1.87810224E+02	# ~nu_muL
1000015	1.36395255E+02	# ~tau_1
2000015	2.07528018E+02	# ~tau_2
1000016	1.86942145E+02	# ~nu_tauL
1000021	6.03561040E+02	# ~g
1000022	9.89200644E+01	# ~chi_10
1000023	1.76248916E+02	# ~chi_20
1000025	-3.57870532E+02	# ~chi_30
1000035	3.77017717E+02	# ~chi_40
1000024	1.75568747E+02	# ~chi_1+
1000037	3.77194407E+02	# ~chi_2+

#

BLOCK NMIX # Neutralino Mixing Matrix

1	1	9.84337446E-01	# N_11
1	2	-6.25292026E-02	# N_12
1	3	1.54406991E-01	# N_13
1	4	-5.76920450E-02	# N_14
2	1	1.12653886E-01	# N_21
2	2	9.40622674E-01	# N_22
2	3	-2.77623463E-01	# N_23
2	4	1.59572240E-01	# N_24
3	1	6.15283938E-02	# N_31
3	2	-9.19478832E-02	# N_32
3	3	-6.94945017E-01	# N_33

```

3 4      -7.10500716E-01  # N_34
4 1       1.20843498E-01  # N_41
4 2      -3.20725226E-01  # N_42
4 3      -6.45085357E-01  # N_43
4 4       6.82932691E-01  # N_44
#
BLOCK UMIK  # Chargino Mixing Matrix U
1 1      -9.12748331E-01  # U_11
1 2       4.08522319E-01  # U_12
2 1       4.08522319E-01  # U_21
2 2       9.12748331E-01  # U_22
#
BLOCK VMIX  # Chargino Mixing Matrix V
1 1      -9.71766502E-01  # V_11
1 2       2.35944624E-01  # V_12
2 1       2.35944624E-01  # V_21
2 2       9.71766502E-01  # V_22
#
BLOCK STOPMIX  # Stop Mixing Matrix
1 1       5.50903293E-01  # cos(theta_t)
1 2       8.34569087E-01  # sin(theta_t)
2 1      -8.34569087E-01  # -sin(theta_t)
2 2       5.50903293E-01  # cos(theta_t)
#
BLOCK SBOTMIX  # Sbottom Mixing Matrix
1 1       9.21378487E-01  # cos(theta_b)
1 2       3.88666546E-01  # sin(theta_b)
2 1      -3.88666546E-01  # -sin(theta_b)
2 2       9.21378487E-01  # cos(theta_b)
#
BLOCK STAUMIX  # Stau Mixing Matrix
1 1       2.80106527E-01  # cos(theta_tau)
1 2       9.59968923E-01  # sin(theta_tau)
2 1      -9.59968923E-01  # -sin(theta_tau)
2 2       2.80106527E-01  # cos(theta_tau)
#
BLOCK ALPHA  # Higgs mixing
          -1.13249720E-01  # Mixing angle in the neutral Higgs boson sector
#
BLOCK HMIK  Q=  4.62965294E+02  # DRbar Higgs Mixing Parameters
1         3.51486069E+02  # mu

```

```

#
BLOCK GAUGE Q= 4.62965294E+02 # The gauge couplings
    1      3.62163400E-01 # gprime(Q) DRbar
    2      6.46905504E-01 # g(Q) DRbar
    3      1.09847635E+00 # g3(Q) DRbar
#
BLOCK AU, AD, AE Q= 4.62965294E+02 # The trilinear couplings
    3 3      -5.11225438E+02 # A_t DRbar
    3 3      -7.92584896E+02 # A_b DRbar
    3 3      -2.54143182E+02 # A_tau DRbar
#
BLOCK Y_X,A_X Q= 4.62965294E+02 # The Yukawa couplings
    3 3      1.35709601E+00 # y_t DRbar
    3 3      2.10275093E-01 # y_b DRbar
    3 3      1.55612239E-01 # y_tau DRbar
#
#
#
# =====
# |The decay table|
# =====
#
# The multi-body decays for the inos and sfermions are included.
#
# The loop induced decays for the gluino, neutralinos and stops
# are included.
#
# The SUSY decays of the top quark are included.
#
#
#
# PDG      Width
DECAY      6      1.50609870E+00 # top decays
#          BR      NDA      ID1      ID2
    1.00000000E+00      2          5          24 # BR(t -> b W+)
    0.00000000E+00      2          5          37 # BR(t -> b H+)
    0.00000000E+00      2      1000006      1000022 # BR(t -> ~t_1 ~chi_10)
    0.00000000E+00      2      1000006      1000023 # BR(t -> ~t_1 ~chi_20)
    0.00000000E+00      2      1000006      1000025 # BR(t -> ~t_1 ~chi_30)
    0.00000000E+00      2      1000006      1000035 # BR(t -> ~t_1 ~chi_40)
    0.00000000E+00      2      2000006      1000022 # BR(t -> ~t_2 ~chi_10)
    0.00000000E+00      2      2000006      1000023 # BR(t -> ~t_2 ~chi_20)

```

	0.00000000E+00	2	2000006	1000025	# BR(t -> \tilde{t}_2 $\tilde{\chi}_{30}$)
	0.00000000E+00	2	2000006	1000035	# BR(t -> \tilde{t}_2 $\tilde{\chi}_{40}$)

#

#	PDG	Width			
DECAY	1000021	4.85459975E+00	# gluino decays		
#	BR	NDA	ID1	ID2	
	1.76180098E-02	2	1000001	-1	# BR(\tilde{g} -> \tilde{d}_L db)
	1.76180098E-02	2	-1000001	1	# BR(\tilde{g} -> \tilde{d}_L^* d)
	5.39508838E-02	2	2000001	-1	# BR(\tilde{g} -> \tilde{d}_R db)
	5.39508838E-02	2	-2000001	1	# BR(\tilde{g} -> \tilde{d}_R^* d)
	2.37062902E-02	2	1000002	-2	# BR(\tilde{g} -> \tilde{u}_L ub)
	2.37062902E-02	2	-1000002	2	# BR(\tilde{g} -> \tilde{u}_L^* u)
	5.23780813E-02	2	2000002	-2	# BR(\tilde{g} -> \tilde{u}_R ub)
	5.23780813E-02	2	-2000002	2	# BR(\tilde{g} -> \tilde{u}_R^* u)
	1.76180098E-02	2	1000003	-3	# BR(\tilde{g} -> \tilde{s}_L sb)
	1.76180098E-02	2	-1000003	3	# BR(\tilde{g} -> \tilde{s}_L^* s)
	5.39508838E-02	2	2000003	-3	# BR(\tilde{g} -> \tilde{s}_R sb)
	5.39508838E-02	2	-2000003	3	# BR(\tilde{g} -> \tilde{s}_R^* s)
	2.37062902E-02	2	1000004	-4	# BR(\tilde{g} -> \tilde{c}_L cb)
	2.37062902E-02	2	-1000004	4	# BR(\tilde{g} -> \tilde{c}_L^* c)
	5.23780813E-02	2	2000004	-4	# BR(\tilde{g} -> \tilde{c}_R cb)
	5.23780813E-02	2	-2000004	4	# BR(\tilde{g} -> \tilde{c}_R^* c)
	1.01674937E-01	2	1000005	-5	# BR(\tilde{g} -> \tilde{b}_1 bb)
	1.01674937E-01	2	-1000005	5	# BR(\tilde{g} -> \tilde{b}_1^* b)
	5.53319969E-02	2	2000005	-5	# BR(\tilde{g} -> \tilde{b}_2 bb)
	5.53319969E-02	2	-2000005	5	# BR(\tilde{g} -> \tilde{b}_2^* b)
	4.76865361E-02	2	1000006	-6	# BR(\tilde{g} -> \tilde{t}_1 tb)
	4.76865361E-02	2	-1000006	6	# BR(\tilde{g} -> \tilde{t}_1^* t)
	0.00000000E+00	2	2000006	-6	# BR(\tilde{g} -> \tilde{t}_2 tb)
	0.00000000E+00	2	-2000006	6	# BR(\tilde{g} -> \tilde{t}_2^* t)

#

#	PDG	Width			
DECAY	1000006	2.06530974E+00	# stop1 decays		
#	BR	NDA	ID1	ID2	
	1.76720929E-01	2	1000022	6	# BR(\tilde{t}_1 -> $\tilde{\chi}_{10}$ t)
	1.26493082E-01	2	1000023	6	# BR(\tilde{t}_1 -> $\tilde{\chi}_{20}$ t)
	0.00000000E+00	2	1000025	6	# BR(\tilde{t}_1 -> $\tilde{\chi}_{30}$ t)
	0.00000000E+00	2	1000035	6	# BR(\tilde{t}_1 -> $\tilde{\chi}_{40}$ t)
	6.78820856E-01	2	1000024	5	# BR(\tilde{t}_1 -> $\tilde{\chi}_{1+}$ b)
	1.79651325E-02	2	1000037	5	# BR(\tilde{t}_1 -> $\tilde{\chi}_{2+}$ b)
	0.00000000E+00	2	1000021	6	# BR(\tilde{t}_1 -> \tilde{g} t)

0.00000000E+00	2	1000005	37	# BR($\tilde{t}_1 \rightarrow \tilde{b}_1$ H+)
0.00000000E+00	2	2000005	37	# BR($\tilde{t}_1 \rightarrow \tilde{b}_2$ H+)
0.00000000E+00	2	1000005	24	# BR($\tilde{t}_1 \rightarrow \tilde{b}_1$ W+)
0.00000000E+00	2	2000005	24	# BR($\tilde{t}_1 \rightarrow \tilde{b}_2$ W+)

#

#	PDG	Width		
DECAY	2000006	7.07039620E+00	# stop2 decays	
#	BR	NDA	ID1	ID2

2.63043489E-02	2	1000022	6	# BR($\tilde{t}_2 \rightarrow \tilde{\chi}_{10} t$)
9.04476605E-02	2	1000023	6	# BR($\tilde{t}_2 \rightarrow \tilde{\chi}_{20} t$)
4.42222844E-02	2	1000025	6	# BR($\tilde{t}_2 \rightarrow \tilde{\chi}_{30} t$)
1.96823757E-01	2	1000035	6	# BR($\tilde{t}_2 \rightarrow \tilde{\chi}_{40} t$)
2.29818044E-01	2	1000024	5	# BR($\tilde{t}_2 \rightarrow \tilde{\chi}_{1+} b$)
2.01693594E-01	2	1000037	5	# BR($\tilde{t}_2 \rightarrow \tilde{\chi}_{2+} b$)
0.00000000E+00	2	1000021	6	# BR($\tilde{t}_2 \rightarrow \tilde{g} t$)
3.81187184E-02	2	1000006	25	# BR($\tilde{t}_2 \rightarrow \tilde{t}_1 h$)
0.00000000E+00	2	1000006	35	# BR($\tilde{t}_2 \rightarrow \tilde{t}_1 H$)
0.00000000E+00	2	1000006	36	# BR($\tilde{t}_2 \rightarrow \tilde{t}_1 A$)
0.00000000E+00	2	1000005	37	# BR($\tilde{t}_2 \rightarrow \tilde{b}_1 H+$)
0.00000000E+00	2	2000005	37	# BR($\tilde{t}_2 \rightarrow \tilde{b}_2 H+$)
1.72571593E-01	2	1000006	23	# BR($\tilde{t}_2 \rightarrow \tilde{t}_1 Z$)
0.00000000E+00	2	1000005	24	# BR($\tilde{t}_2 \rightarrow \tilde{b}_1 W+$)
0.00000000E+00	2	2000005	24	# BR($\tilde{t}_2 \rightarrow \tilde{b}_2 W+$)

#

#	PDG	Width		
DECAY	1000005	3.79216587E+00	# sbottom1 decays	
#	BR	NDA	ID1	ID2

4.61784398E-02	2	1000022	5	# BR($\tilde{b}_1 \rightarrow \tilde{\chi}_{10} b$)
3.44388596E-01	2	1000023	5	# BR($\tilde{b}_1 \rightarrow \tilde{\chi}_{20} b$)
5.08897163E-03	2	1000025	5	# BR($\tilde{b}_1 \rightarrow \tilde{\chi}_{30} b$)
1.06407337E-02	2	1000035	5	# BR($\tilde{b}_1 \rightarrow \tilde{\chi}_{40} b$)
4.49199440E-01	2	-1000024	6	# BR($\tilde{b}_1 \rightarrow \tilde{\chi}_{1-} t$)
0.00000000E+00	2	-1000037	6	# BR($\tilde{b}_1 \rightarrow \tilde{\chi}_{2-} t$)
0.00000000E+00	2	1000021	5	# BR($\tilde{b}_1 \rightarrow \tilde{g} b$)
0.00000000E+00	2	1000006	-37	# BR($\tilde{b}_1 \rightarrow \tilde{t}_1 H-$)
0.00000000E+00	2	2000006	-37	# BR($\tilde{b}_1 \rightarrow \tilde{t}_2 H-$)
1.44503819E-01	2	1000006	-24	# BR($\tilde{b}_1 \rightarrow \tilde{t}_1 W-$)
0.00000000E+00	2	2000006	-24	# BR($\tilde{b}_1 \rightarrow \tilde{t}_2 W-$)

#

#	PDG	Width		
DECAY	2000005	9.30237022E-01	# sbottom2 decays	

#	BR	NDA	ID1	ID2	
	2.18042454E-01	2	1000022	5	# BR($\sim b_2 \rightarrow \sim \chi_{10} b$)
	1.63625100E-01	2	1000023	5	# BR($\sim b_2 \rightarrow \sim \chi_{20} b$)
	4.87739508E-02	2	1000025	5	# BR($\sim b_2 \rightarrow \sim \chi_{30} b$)
	7.28430988E-02	2	1000035	5	# BR($\sim b_2 \rightarrow \sim \chi_{40} b$)
	2.17719337E-01	2	-1000024	6	# BR($\sim b_2 \rightarrow \sim \chi_{1-} t$)
	0.00000000E+00	2	-1000037	6	# BR($\sim b_2 \rightarrow \sim \chi_{2-} t$)
	0.00000000E+00	2	1000021	5	# BR($\sim b_2 \rightarrow \sim g \quad b$)
	0.00000000E+00	2	1000005	25	# BR($\sim b_2 \rightarrow \sim b_1 \quad h$)
	0.00000000E+00	2	1000005	35	# BR($\sim b_2 \rightarrow \sim b_1 \quad H$)
	0.00000000E+00	2	1000005	36	# BR($\sim b_2 \rightarrow \sim b_1 \quad A$)
	0.00000000E+00	2	1000006	-37	# BR($\sim b_2 \rightarrow \sim t_1 \quad H^-$)
	0.00000000E+00	2	2000006	-37	# BR($\sim b_2 \rightarrow \sim t_2 \quad H^-$)
	0.00000000E+00	2	1000005	23	# BR($\sim b_2 \rightarrow \sim b_1 \quad Z$)
	2.78996060E-01	2	1000006	-24	# BR($\sim b_2 \rightarrow \sim t_1 \quad W^-$)
	0.00000000E+00	2	2000006	-24	# BR($\sim b_2 \rightarrow \sim t_2 \quad W^-$)

#

#	PDG	Width			
DECAY	1000002	5.56209623E+00	# sup_L decays		
#	BR	NDA	ID1	ID2	
	5.04724246E-03	2	1000022	2	# BR($\sim u_L \rightarrow \sim \chi_{10} u$)
	3.17395881E-01	2	1000023	2	# BR($\sim u_L \rightarrow \sim \chi_{20} u$)
	9.89628847E-04	2	1000025	2	# BR($\sim u_L \rightarrow \sim \chi_{30} u$)
	1.15831154E-02	2	1000035	2	# BR($\sim u_L \rightarrow \sim \chi_{40} u$)
	6.50599773E-01	2	1000024	1	# BR($\sim u_L \rightarrow \sim \chi_{1+} d$)
	1.43843593E-02	2	1000037	1	# BR($\sim u_L \rightarrow \sim \chi_{2+} d$)
	0.00000000E+00	2	1000021	2	# BR($\sim u_L \rightarrow \sim g \quad u$)

#

#	PDG	Width			
DECAY	2000002	1.05910452E+00	# sup_R decays		
#	BR	NDA	ID1	ID2	
	9.83357095E-01	2	1000022	2	# BR($\sim u_R \rightarrow \sim \chi_{10} u$)
	1.10363000E-02	2	1000023	2	# BR($\sim u_R \rightarrow \sim \chi_{20} u$)
	1.32287897E-03	2	1000025	2	# BR($\sim u_R \rightarrow \sim \chi_{30} u$)
	4.28372575E-03	2	1000035	2	# BR($\sim u_R \rightarrow \sim \chi_{40} u$)
	0.00000000E+00	2	1000024	1	# BR($\sim u_R \rightarrow \sim \chi_{1+} d$)
	0.00000000E+00	2	1000037	1	# BR($\sim u_R \rightarrow \sim \chi_{2+} d$)
	0.00000000E+00	2	1000021	2	# BR($\sim u_R \rightarrow \sim g \quad u$)

#

#	PDG	Width			
DECAY	1000001	5.35470938E+00	# sdown_L decays		

#	BR	NDA	ID1	ID2	
	2.35733116E-02	2	1000022	1	# BR($\tilde{d}_L \rightarrow \tilde{\chi}_{10} d$)
	3.07006812E-01	2	1000023	1	# BR($\tilde{d}_L \rightarrow \tilde{\chi}_{20} d$)
	1.72033892E-03	2	1000025	1	# BR($\tilde{d}_L \rightarrow \tilde{\chi}_{30} d$)
	1.64027859E-02	2	1000035	1	# BR($\tilde{d}_L \rightarrow \tilde{\chi}_{40} d$)
	6.04624253E-01	2	-1000024	2	# BR($\tilde{d}_L \rightarrow \tilde{\chi}_{1-} u$)
	4.66724989E-02	2	-1000037	2	# BR($\tilde{d}_L \rightarrow \tilde{\chi}_{2-} u$)
	0.00000000E+00	2	1000021	1	# BR($\tilde{d}_L \rightarrow \tilde{g} d$)

#

#	PDG	Width	
DECAY	2000001	2.64248238E-01	# sdown_R decays
#	BR	NDA	ID1 ID2
	9.83395634E-01	2	1000022 1 # BR($\tilde{d}_R \rightarrow \tilde{\chi}_{10} d$)
	1.10304127E-02	2	1000023 1 # BR($\tilde{d}_R \rightarrow \tilde{\chi}_{20} d$)
	1.31629502E-03	2	1000025 1 # BR($\tilde{d}_R \rightarrow \tilde{\chi}_{30} d$)
	4.25765842E-03	2	1000035 1 # BR($\tilde{d}_R \rightarrow \tilde{\chi}_{40} d$)
	0.00000000E+00	2	-1000024 2 # BR($\tilde{d}_R \rightarrow \tilde{\chi}_{1-} u$)
	0.00000000E+00	2	-1000037 2 # BR($\tilde{d}_R \rightarrow \tilde{\chi}_{2-} u$)
	0.00000000E+00	2	1000021 1 # BR($\tilde{d}_R \rightarrow \tilde{g} d$)

#

#	PDG	Width	
DECAY	1000004	5.56209623E+00	# scharm_L decays
#	BR	NDA	ID1 ID2
	5.04724246E-03	2	1000022 4 # BR($\tilde{c}_L \rightarrow \tilde{\chi}_{10} c$)
	3.17395881E-01	2	1000023 4 # BR($\tilde{c}_L \rightarrow \tilde{\chi}_{20} c$)
	9.89628847E-04	2	1000025 4 # BR($\tilde{c}_L \rightarrow \tilde{\chi}_{30} c$)
	1.15831154E-02	2	1000035 4 # BR($\tilde{c}_L \rightarrow \tilde{\chi}_{40} c$)
	6.50599773E-01	2	1000024 3 # BR($\tilde{c}_L \rightarrow \tilde{\chi}_{1+} s$)
	1.43843593E-02	2	1000037 3 # BR($\tilde{c}_L \rightarrow \tilde{\chi}_{2+} s$)
	0.00000000E+00	2	1000021 4 # BR($\tilde{c}_L \rightarrow \tilde{g} c$)

#

#	PDG	Width	
DECAY	2000004	1.05910452E+00	# scharm_R decays
#	BR	NDA	ID1 ID2
	9.83357095E-01	2	1000022 4 # BR($\tilde{c}_R \rightarrow \tilde{\chi}_{10} c$)
	1.10363000E-02	2	1000023 4 # BR($\tilde{c}_R \rightarrow \tilde{\chi}_{20} c$)
	1.32287897E-03	2	1000025 4 # BR($\tilde{c}_R \rightarrow \tilde{\chi}_{30} c$)
	4.28372575E-03	2	1000035 4 # BR($\tilde{c}_R \rightarrow \tilde{\chi}_{40} c$)
	0.00000000E+00	2	1000024 3 # BR($\tilde{c}_R \rightarrow \tilde{\chi}_{1+} s$)
	0.00000000E+00	2	1000037 3 # BR($\tilde{c}_R \rightarrow \tilde{\chi}_{2+} s$)
	0.00000000E+00	2	1000021 4 # BR($\tilde{c}_R \rightarrow \tilde{g} c$)

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#
#          PDG          Width
DECAY    1000003      5.35470938E+00  # ssstrange_L decays
#          BR          NDA      ID1      ID2
      2.35733116E-02      2      1000022      3  # BR(~s_L -> ~chi_10 s)
      3.07006812E-01      2      1000023      3  # BR(~s_L -> ~chi_20 s)
      1.72033892E-03      2      1000025      3  # BR(~s_L -> ~chi_30 s)
      1.64027859E-02      2      1000035      3  # BR(~s_L -> ~chi_40 s)
      6.04624253E-01      2     -1000024      4  # BR(~s_L -> ~chi_1- c)
      4.66724989E-02      2     -1000037      4  # BR(~s_L -> ~chi_2- c)
      0.00000000E+00      2      1000021      3  # BR(~s_L -> ~g      s)

#
#          PDG          Width
DECAY    2000003      2.64248238E-01  # ssstrange_R decays
#          BR          NDA      ID1      ID2
      9.83395634E-01      2      1000022      3  # BR(~s_R -> ~chi_10 s)
      1.10304127E-02      2      1000023      3  # BR(~s_R -> ~chi_20 s)
      1.31629502E-03      2      1000025      3  # BR(~s_R -> ~chi_30 s)
      4.25765842E-03      2      1000035      3  # BR(~s_R -> ~chi_40 s)
      0.00000000E+00      2     -1000024      4  # BR(~s_R -> ~chi_1- c)
      0.00000000E+00      2     -1000037      4  # BR(~s_R -> ~chi_2- c)
      0.00000000E+00      2      1000021      3  # BR(~s_R -> ~g      s)

#
#          PDG          Width
DECAY    1000011      2.53683595E-01  # selectron_L decays
#          BR          NDA      ID1      ID2
      4.19337361E-01      2      1000022      11  # BR(~e_L -> ~chi_10 e-)
      2.11871941E-01      2      1000023      11  # BR(~e_L -> ~chi_20 e-)
      0.00000000E+00      2      1000025      11  # BR(~e_L -> ~chi_30 e-)
      0.00000000E+00      2      1000035      11  # BR(~e_L -> ~chi_40 e-)
      3.68790698E-01      2     -1000024      12  # BR(~e_L -> ~chi_1- nu_e)
      0.00000000E+00      2     -1000037      12  # BR(~e_L -> ~chi_2- nu_e)

#
#          PDG          Width
DECAY    2000011      1.93168017E-01  # selectron_R decays
#          BR          NDA      ID1      ID2
      1.00000000E+00      2      1000022      11  # BR(~e_R -> ~chi_10 e-)
      0.00000000E+00      2      1000023      11  # BR(~e_R -> ~chi_20 e-)
      0.00000000E+00      2      1000025      11  # BR(~e_R -> ~chi_30 e-)
      0.00000000E+00      2      1000035      11  # BR(~e_R -> ~chi_40 e-)
      0.00000000E+00      2     -1000024      12  # BR(~e_R -> ~chi_1- nu_e)

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0.00000000E+00      2      -1000037      12      # BR(~e_R -> ~chi_2- nu_e)
#
#          PDG          Width
DECAY      1000013      2.53683595E-01      # smuon_L decays
#          BR          NDA          ID1          ID2
4.19337361E-01      2          1000022      13      # BR(~mu_L -> ~chi_10 mu-)
2.11871941E-01      2          1000023      13      # BR(~mu_L -> ~chi_20 mu-)
0.00000000E+00      2          1000025      13      # BR(~mu_L -> ~chi_30 mu-)
0.00000000E+00      2          1000035      13      # BR(~mu_L -> ~chi_40 mu-)
3.68790698E-01      2          -1000024      14      # BR(~mu_L -> ~chi_1- nu_mu)
0.00000000E+00      2          -1000037      14      # BR(~mu_L -> ~chi_2- nu_mu)
#
#          PDG          Width
DECAY      2000013      1.93168017E-01      # smuon_R decays
#          BR          NDA          ID1          ID2
1.00000000E+00      2          1000022      13      # BR(~mu_R -> ~chi_10 mu-)
0.00000000E+00      2          1000023      13      # BR(~mu_R -> ~chi_20 mu-)
0.00000000E+00      2          1000025      13      # BR(~mu_R -> ~chi_30 mu-)
0.00000000E+00      2          1000035      13      # BR(~mu_R -> ~chi_40 mu-)
0.00000000E+00      2          -1000024      14      # BR(~mu_R -> ~chi_1- nu_mu)
0.00000000E+00      2          -1000037      14      # BR(~mu_R -> ~chi_2- nu_mu)
#
#          PDG          Width
DECAY      1000015      1.34568207E-01      # stau_1 decays
#          BR          NDA          ID1          ID2
1.00000000E+00      2          1000022      15      # BR(~tau_1 -> ~chi_10 tau-)
0.00000000E+00      2          1000023      15      # BR(~tau_1 -> ~chi_20 tau-)
0.00000000E+00      2          1000025      15      # BR(~tau_1 -> ~chi_30 tau-)
0.00000000E+00      2          1000035      15      # BR(~tau_1 -> ~chi_40 tau-)
0.00000000E+00      2          -1000024      16      # BR(~tau_1 -> ~chi_1- nu_tau)
0.00000000E+00      2          -1000037      16      # BR(~tau_1 -> ~chi_2- nu_tau)
0.00000000E+00      2          1000016      -37      # BR(~tau_1 -> ~nu_tauL H-)
0.00000000E+00      2          1000016      -24      # BR(~tau_1 -> ~nu_tauL W-)
#
#          PDG          Width
DECAY      2000015      3.03123027E-01      # stau_2 decays
#          BR          NDA          ID1          ID2
4.63906167E-01      2          1000022      15      # BR(~tau_2 -> ~chi_10 tau-)
1.96659153E-01      2          1000023      15      # BR(~tau_2 -> ~chi_20 tau-)
0.00000000E+00      2          1000025      15      # BR(~tau_2 -> ~chi_30 tau-)
0.00000000E+00      2          1000035      15      # BR(~tau_2 -> ~chi_40 tau-)

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3.39434680E-01	2	-1000024	16	# BR($\tilde{\tau}_2 \rightarrow \tilde{\chi}_1 - \nu_\tau$)
0.00000000E+00	2	-1000037	16	# BR($\tilde{\tau}_2 \rightarrow \tilde{\chi}_2 - \nu_\tau$)
0.00000000E+00	2	1000016	-37	# BR($\tilde{\tau}_2 \rightarrow \tilde{\nu}_\tau L H^-$)
0.00000000E+00	2	1000016	-24	# BR($\tilde{\tau}_2 \rightarrow \tilde{\nu}_\tau L W^-$)
0.00000000E+00	2	1000015	25	# BR($\tilde{\tau}_2 \rightarrow \tilde{\tau}_1 h$)
0.00000000E+00	2	1000015	35	# BR($\tilde{\tau}_2 \rightarrow \tilde{\tau}_1 H$)
0.00000000E+00	2	1000015	36	# BR($\tilde{\tau}_2 \rightarrow \tilde{\tau}_1 A$)
0.00000000E+00	2	1000015	23	# BR($\tilde{\tau}_2 \rightarrow \tilde{\tau}_1 Z$)

#

#	PDG	Width	# snu_eL decays		
DECAY	1000012	1.73484437E-01	# snu_eL decays		
#	BR	NDA	ID1	ID2	
8.14895139E-01	2	1000022	12	# BR($\tilde{\nu}_e L \rightarrow \tilde{\chi}_10 \nu_e$)	
4.97403776E-02	2	1000023	12	# BR($\tilde{\nu}_e L \rightarrow \tilde{\chi}_20 \nu_e$)	
0.00000000E+00	2	1000025	12	# BR($\tilde{\nu}_e L \rightarrow \tilde{\chi}_30 \nu_e$)	
0.00000000E+00	2	1000035	12	# BR($\tilde{\nu}_e L \rightarrow \tilde{\chi}_40 \nu_e$)	
1.35364484E-01	2	1000024	11	# BR($\tilde{\nu}_e L \rightarrow \tilde{\chi}_1+ e^-$)	
0.00000000E+00	2	1000037	11	# BR($\tilde{\nu}_e L \rightarrow \tilde{\chi}_2+ e^-$)	

#

#	PDG	Width	# snu_muL decays		
DECAY	1000014	1.73484437E-01	# snu_muL decays		
#	BR	NDA	ID1	ID2	
8.14895139E-01	2	1000022	14	# BR($\tilde{\nu}_\mu L \rightarrow \tilde{\chi}_10 \nu_\mu$)	
4.97403776E-02	2	1000023	14	# BR($\tilde{\nu}_\mu L \rightarrow \tilde{\chi}_20 \nu_\mu$)	
0.00000000E+00	2	1000025	14	# BR($\tilde{\nu}_\mu L \rightarrow \tilde{\chi}_30 \nu_\mu$)	
0.00000000E+00	2	1000035	14	# BR($\tilde{\nu}_\mu L \rightarrow \tilde{\chi}_40 \nu_\mu$)	
1.35364484E-01	2	1000024	13	# BR($\tilde{\nu}_\mu L \rightarrow \tilde{\chi}_1+ \mu^-$)	
0.00000000E+00	2	1000037	13	# BR($\tilde{\nu}_\mu L \rightarrow \tilde{\chi}_2+ \mu^-$)	

#

#	PDG	Width	# snu_tauL decays		
DECAY	1000016	1.67039909E-01	# snu_tauL decays		
#	BR	NDA	ID1	ID2	
8.36412025E-01	2	1000022	16	# BR($\tilde{\nu}_\tau L \rightarrow \tilde{\chi}_10 \nu_\tau$)	
4.45980206E-02	2	1000023	16	# BR($\tilde{\nu}_\tau L \rightarrow \tilde{\chi}_20 \nu_\tau$)	
0.00000000E+00	2	1000025	16	# BR($\tilde{\nu}_\tau L \rightarrow \tilde{\chi}_30 \nu_\tau$)	
0.00000000E+00	2	1000035	16	# BR($\tilde{\nu}_\tau L \rightarrow \tilde{\chi}_40 \nu_\tau$)	
1.18989955E-01	2	1000024	15	# BR($\tilde{\nu}_\tau L \rightarrow \tilde{\chi}_1+ \tau^-$)	
0.00000000E+00	2	1000037	15	# BR($\tilde{\nu}_\tau L \rightarrow \tilde{\chi}_2+ \tau^-$)	
0.00000000E+00	2	1000015	-37	# BR($\tilde{\nu}_\tau L \rightarrow \tilde{\tau}_1+ H^-$)	
0.00000000E+00	2	2000015	-37	# BR($\tilde{\nu}_\tau L \rightarrow \tilde{\tau}_2+ H^-$)	
0.00000000E+00	2	1000015	-24	# BR($\tilde{\nu}_\tau L \rightarrow \tilde{\tau}_1+ W^-$)	

#	PDG	Width	#	chargino1+ decays
#	BR	NDA	ID1	ID2
0.00000000E+00	2	1000002	-1	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{u}_L$ db)
0.00000000E+00	2	2000002	-1	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{u}_R$ db)
0.00000000E+00	2	-1000001	2	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{d}_L^*$ u)
0.00000000E+00	2	-2000001	2	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{d}_R^*$ u)
0.00000000E+00	2	1000004	-3	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{c}_L$ sb)
0.00000000E+00	2	2000004	-3	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{c}_R$ sb)
0.00000000E+00	2	-1000003	4	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{s}_L^*$ c)
0.00000000E+00	2	-2000003	4	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{s}_R^*$ c)
0.00000000E+00	2	1000006	-5	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{t}_1$ bb)
0.00000000E+00	2	2000006	-5	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{t}_2$ bb)
0.00000000E+00	2	-1000005	6	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{b}_1^*$ t)
0.00000000E+00	2	-2000005	6	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{b}_2^*$ t)
0.00000000E+00	2	1000012	-11	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\nu}_{eL}$ e+)
0.00000000E+00	2	1000014	-13	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\nu}_{\mu L}$ mu+)
0.00000000E+00	2	1000016	-15	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\nu}_{\tau 1}$ tau+)
0.00000000E+00	2	-1000011	12	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{e}_L^+$ nu_e)
0.00000000E+00	2	-2000011	12	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{e}_R^+$ nu_e)
0.00000000E+00	2	-1000013	14	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\mu}_L^+$ nu_mu)
0.00000000E+00	2	-2000013	14	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\mu}_R^+$ nu_mu)
1.00000000E+00	2	-1000015	16	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\tau}_1$ nu_tau)
0.00000000E+00	2	-2000015	16	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\tau}_2$ nu_tau)
0.00000000E+00	2	1000022	24	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\chi}_{10}$ W+)
0.00000000E+00	2	1000023	24	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\chi}_{20}$ W+)
0.00000000E+00	2	1000025	24	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\chi}_{30}$ W+)
0.00000000E+00	2	1000035	24	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\chi}_{40}$ W+)
0.00000000E+00	2	1000022	37	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\chi}_{10}$ H+)
0.00000000E+00	2	1000023	37	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\chi}_{20}$ H+)
0.00000000E+00	2	1000025	37	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\chi}_{30}$ H+)
0.00000000E+00	2	1000035	37	# BR($\tilde{\chi}_{1+} \rightarrow \tilde{\chi}_{40}$ H+)

#	PDG	Width	#	chargino2+ decays
#	BR	NDA	ID1	ID2
0.00000000E+00	2	1000002	-1	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{u}_L$ db)
0.00000000E+00	2	2000002	-1	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{u}_R$ db)
0.00000000E+00	2	-1000001	2	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{d}_L^*$ u)

0.00000000E+00	2	-2000001	2	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{d}_R^* u$)
0.00000000E+00	2	1000004	-3	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{c}_L sb$)
0.00000000E+00	2	2000004	-3	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{c}_R sb$)
0.00000000E+00	2	-1000003	4	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{s}_L^* c$)
0.00000000E+00	2	-2000003	4	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{s}_R^* c$)
0.00000000E+00	2	1000006	-5	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{t}_1 bb$)
0.00000000E+00	2	2000006	-5	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{t}_2 bb$)
0.00000000E+00	2	-1000005	6	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{b}_1^* t$)
0.00000000E+00	2	-2000005	6	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{b}_2^* t$)
1.96925255E-02	2	1000012	-11	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\nu}_{eL} e^+$)
1.96925255E-02	2	1000014	-13	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\nu}_{\mu L} \mu^+$)
2.66937138E-02	2	1000016	-15	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\nu}_{\tau L} \tau^+$)
5.23600711E-02	2	-1000011	12	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{e}_L^+ \nu_e$)
0.00000000E+00	2	-2000011	12	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{e}_R^+ \nu_e$)
5.23600711E-02	2	-1000013	14	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\mu}_L^+ \nu_\mu$)
0.00000000E+00	2	-2000013	14	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\mu}_R^+ \nu_\mu$)
2.27029940E-04	2	-1000015	16	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\tau}_1^+ \nu_\tau$)
5.67355363E-02	2	-2000015	16	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\tau}_2^+ \nu_\tau$)
2.42517968E-01	2	1000024	23	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{1+} Z$)
6.41934286E-02	2	1000022	24	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{10} W^+$)
2.95919427E-01	2	1000023	24	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{20} W^+$)
0.00000000E+00	2	1000025	24	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{30} W^+$)
0.00000000E+00	2	1000035	24	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{40} W^+$)
1.69607703E-01	2	1000024	25	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{1+} h$)
0.00000000E+00	2	1000024	35	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{1+} H$)
0.00000000E+00	2	1000024	36	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{1+} A$)
0.00000000E+00	2	1000022	37	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{10} H^+$)
0.00000000E+00	2	1000023	37	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{20} H^+$)
0.00000000E+00	2	1000025	37	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{30} H^+$)
0.00000000E+00	2	1000035	37	# BR($\tilde{\chi}_{2+} \rightarrow \tilde{\chi}_{40} H^+$)

#

#	PDG	Width	
DECAY	1000022	0.00000000E+00	# neutralino1 decays

#

#	PDG	Width	
DECAY	1000023	1.64735255E-02	# neutralino2 decays

#	BR	NDA	ID1	ID2	
0.00000000E+00	2	1000022	23	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{10} Z$)	
0.00000000E+00	2	1000024	-24	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{1+} W^-$)	
0.00000000E+00	2	-1000024	24	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{1-} W^+$)	
0.00000000E+00	2	1000037	-24	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{2+} W^-$)	

0.00000000E+00	2	-1000037	24	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{2-} W^+$)
0.00000000E+00	2	1000022	25	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{10} h$)
0.00000000E+00	2	1000022	35	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{10} H$)
0.00000000E+00	2	1000022	36	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{10} A$)
0.00000000E+00	2	1000024	-37	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{1+} H^-$)
0.00000000E+00	2	-1000024	37	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{1-} H^+$)
0.00000000E+00	2	1000037	-37	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{2+} H^-$)
0.00000000E+00	2	-1000037	37	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\chi}_{2-} H^+$)
0.00000000E+00	2	1000002	-2	# BR($\tilde{\chi}_{20} \rightarrow \tilde{u}_L ub$)
0.00000000E+00	2	-1000002	2	# BR($\tilde{\chi}_{20} \rightarrow \tilde{u}_L^* u$)
0.00000000E+00	2	2000002	-2	# BR($\tilde{\chi}_{20} \rightarrow \tilde{u}_R ub$)
0.00000000E+00	2	-2000002	2	# BR($\tilde{\chi}_{20} \rightarrow \tilde{u}_R^* u$)
0.00000000E+00	2	1000001	-1	# BR($\tilde{\chi}_{20} \rightarrow \tilde{d}_L db$)
0.00000000E+00	2	-1000001	1	# BR($\tilde{\chi}_{20} \rightarrow \tilde{d}_L^* d$)
0.00000000E+00	2	2000001	-1	# BR($\tilde{\chi}_{20} \rightarrow \tilde{d}_R db$)
0.00000000E+00	2	-2000001	1	# BR($\tilde{\chi}_{20} \rightarrow \tilde{d}_R^* d$)
0.00000000E+00	2	1000004	-4	# BR($\tilde{\chi}_{20} \rightarrow \tilde{c}_L cb$)
0.00000000E+00	2	-1000004	4	# BR($\tilde{\chi}_{20} \rightarrow \tilde{c}_L^* c$)
0.00000000E+00	2	2000004	-4	# BR($\tilde{\chi}_{20} \rightarrow \tilde{c}_R cb$)
0.00000000E+00	2	-2000004	4	# BR($\tilde{\chi}_{20} \rightarrow \tilde{c}_R^* c$)
0.00000000E+00	2	1000003	-3	# BR($\tilde{\chi}_{20} \rightarrow \tilde{s}_L sb$)
0.00000000E+00	2	-1000003	3	# BR($\tilde{\chi}_{20} \rightarrow \tilde{s}_L^* s$)
0.00000000E+00	2	2000003	-3	# BR($\tilde{\chi}_{20} \rightarrow \tilde{s}_R sb$)
0.00000000E+00	2	-2000003	3	# BR($\tilde{\chi}_{20} \rightarrow \tilde{s}_R^* s$)
0.00000000E+00	2	1000006	-6	# BR($\tilde{\chi}_{20} \rightarrow \tilde{t}_1 tb$)
0.00000000E+00	2	-1000006	6	# BR($\tilde{\chi}_{20} \rightarrow \tilde{t}_1^* t$)
0.00000000E+00	2	2000006	-6	# BR($\tilde{\chi}_{20} \rightarrow \tilde{t}_2 tb$)
0.00000000E+00	2	-2000006	6	# BR($\tilde{\chi}_{20} \rightarrow \tilde{t}_2^* t$)
0.00000000E+00	2	1000005	-5	# BR($\tilde{\chi}_{20} \rightarrow \tilde{b}_1 bb$)
0.00000000E+00	2	-1000005	5	# BR($\tilde{\chi}_{20} \rightarrow \tilde{b}_1^* b$)
0.00000000E+00	2	2000005	-5	# BR($\tilde{\chi}_{20} \rightarrow \tilde{b}_2 bb$)
0.00000000E+00	2	-2000005	5	# BR($\tilde{\chi}_{20} \rightarrow \tilde{b}_2^* b$)
0.00000000E+00	2	1000011	-11	# BR($\tilde{\chi}_{20} \rightarrow \tilde{e}_L e^+$)
0.00000000E+00	2	-1000011	11	# BR($\tilde{\chi}_{20} \rightarrow \tilde{e}_L e^-$)
3.29566665E-02	2	2000011	-11	# BR($\tilde{\chi}_{20} \rightarrow \tilde{e}_R e^+$)
3.29566665E-02	2	-2000011	11	# BR($\tilde{\chi}_{20} \rightarrow \tilde{e}_R e^-$)
0.00000000E+00	2	1000013	-13	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\mu}_L \mu^+$)
0.00000000E+00	2	-1000013	13	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\mu}_L \mu^-$)
3.29566665E-02	2	2000013	-13	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\mu}_R \mu^+$)
3.29566665E-02	2	-2000013	13	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\mu}_R \mu^-$)
4.34086667E-01	2	1000015	-15	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\tau}_1 \tau^+$)

4.34086667E-01	2	-1000015	15	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\tau}_{1+} \tau^-$)
0.00000000E+00	2	2000015	-15	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\tau}_{2-} \tau^+$)
0.00000000E+00	2	-2000015	15	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\tau}_{2+} \tau^-$)
0.00000000E+00	2	1000012	-12	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\nu}_e L \nu_{eb}$)
0.00000000E+00	2	-1000012	12	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\nu}_e L^* \nu_e$)
0.00000000E+00	2	1000014	-14	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\nu}_\mu L \nu_{\mu b}$)
0.00000000E+00	2	-1000014	14	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\nu}_\mu L^* \nu_\mu$)
0.00000000E+00	2	1000016	-16	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\nu}_\tau \tau \nu_{\tau b}$)
0.00000000E+00	2	-1000016	16	# BR($\tilde{\chi}_{20} \rightarrow \tilde{\nu}_\tau \tau^* \nu_\tau$)

#

#	PDG	Width	# neutralino3 decays		
DECA	1000025	1.92862382E+00	# neutralino3 decays		
#	BR	NDA	ID1	ID2	
1.15279015E-01	2	1000022	23	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{10} Z$)	
2.11120573E-01	2	1000023	23	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{20} Z$)	
2.97321131E-01	2	1000024	-24	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{1+} W^-$)	
2.97321131E-01	2	-1000024	24	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{1-} W^+$)	
0.00000000E+00	2	1000037	-24	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{2+} W^-$)	
0.00000000E+00	2	-1000037	24	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{2-} W^+$)	
1.87138985E-02	2	1000022	25	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{10} h$)	
0.00000000E+00	2	1000022	35	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{10} H$)	
0.00000000E+00	2	1000022	36	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{10} A$)	
1.14519963E-02	2	1000023	25	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{20} h$)	
0.00000000E+00	2	1000023	35	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{20} H$)	
0.00000000E+00	2	1000023	36	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{20} A$)	
0.00000000E+00	2	1000024	-37	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{1+} H^-$)	
0.00000000E+00	2	-1000024	37	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{1-} H^+$)	
0.00000000E+00	2	1000037	-37	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{2+} H^-$)	
0.00000000E+00	2	-1000037	37	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\chi}_{2-} H^+$)	
0.00000000E+00	2	1000002	-2	# BR($\tilde{\chi}_{30} \rightarrow \tilde{u}_L \bar{u} b$)	
0.00000000E+00	2	-1000002	2	# BR($\tilde{\chi}_{30} \rightarrow \tilde{u}_L^* u$)	
0.00000000E+00	2	2000002	-2	# BR($\tilde{\chi}_{30} \rightarrow \tilde{u}_R \bar{u} b$)	
0.00000000E+00	2	-2000002	2	# BR($\tilde{\chi}_{30} \rightarrow \tilde{u}_R^* u$)	
0.00000000E+00	2	1000001	-1	# BR($\tilde{\chi}_{30} \rightarrow \tilde{d}_L \bar{d} b$)	
0.00000000E+00	2	-1000001	1	# BR($\tilde{\chi}_{30} \rightarrow \tilde{d}_L^* d$)	
0.00000000E+00	2	2000001	-1	# BR($\tilde{\chi}_{30} \rightarrow \tilde{d}_R \bar{d} b$)	
0.00000000E+00	2	-2000001	1	# BR($\tilde{\chi}_{30} \rightarrow \tilde{d}_R^* d$)	
0.00000000E+00	2	1000004	-4	# BR($\tilde{\chi}_{30} \rightarrow \tilde{c}_L \bar{c} b$)	
0.00000000E+00	2	-1000004	4	# BR($\tilde{\chi}_{30} \rightarrow \tilde{c}_L^* c$)	
0.00000000E+00	2	2000004	-4	# BR($\tilde{\chi}_{30} \rightarrow \tilde{c}_R \bar{c} b$)	
0.00000000E+00	2	-2000004	4	# BR($\tilde{\chi}_{30} \rightarrow \tilde{c}_R^* c$)	

0.00000000E+00	2	1000003	-3	# BR($\tilde{\chi}_{30} \rightarrow \tilde{s}_L$	sb)
0.00000000E+00	2	-1000003	3	# BR($\tilde{\chi}_{30} \rightarrow \tilde{s}_L^*$	s)
0.00000000E+00	2	2000003	-3	# BR($\tilde{\chi}_{30} \rightarrow \tilde{s}_R$	sb)
0.00000000E+00	2	-2000003	3	# BR($\tilde{\chi}_{30} \rightarrow \tilde{s}_R^*$	s)
0.00000000E+00	2	1000006	-6	# BR($\tilde{\chi}_{30} \rightarrow \tilde{t}_1$	tb)
0.00000000E+00	2	-1000006	6	# BR($\tilde{\chi}_{30} \rightarrow \tilde{t}_1^*$	t)
0.00000000E+00	2	2000006	-6	# BR($\tilde{\chi}_{30} \rightarrow \tilde{t}_2$	tb)
0.00000000E+00	2	-2000006	6	# BR($\tilde{\chi}_{30} \rightarrow \tilde{t}_2^*$	t)
0.00000000E+00	2	1000005	-5	# BR($\tilde{\chi}_{30} \rightarrow \tilde{b}_1$	bb)
0.00000000E+00	2	-1000005	5	# BR($\tilde{\chi}_{30} \rightarrow \tilde{b}_1^*$	b)
0.00000000E+00	2	2000005	-5	# BR($\tilde{\chi}_{30} \rightarrow \tilde{b}_2$	bb)
0.00000000E+00	2	-2000005	5	# BR($\tilde{\chi}_{30} \rightarrow \tilde{b}_2^*$	b)
6.15727811E-04	2	1000011	-11	# BR($\tilde{\chi}_{30} \rightarrow \tilde{e}_L-$	e+)
6.15727811E-04	2	-1000011	11	# BR($\tilde{\chi}_{30} \rightarrow \tilde{e}_L+$	e-)
1.16411010E-03	2	2000011	-11	# BR($\tilde{\chi}_{30} \rightarrow \tilde{e}_R-$	e+)
1.16411010E-03	2	-2000011	11	# BR($\tilde{\chi}_{30} \rightarrow \tilde{e}_R+$	e-)
6.15727811E-04	2	1000013	-13	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\mu}_L-$	μ +))
6.15727811E-04	2	-1000013	13	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\mu}_L+$	μ -)
1.16411010E-03	2	2000013	-13	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\mu}_R-$	μ +))
1.16411010E-03	2	-2000013	13	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\mu}_R+$	μ -)
4.92152638E-03	2	1000015	-15	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\tau}_1-$	τ +))
4.92152638E-03	2	-1000015	15	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\tau}_1+$	τ -)
6.41442155E-03	2	2000015	-15	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\tau}_2-$	τ +))
6.41442155E-03	2	-2000015	15	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\tau}_2+$	τ -)
3.15943787E-03	2	1000012	-12	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\nu}_eL$	ν_e b)
3.15943787E-03	2	-1000012	12	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\nu}_eL^*$	ν_e)
3.15943787E-03	2	1000014	-14	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\nu}_\mu L$	ν_μ b)
3.15943787E-03	2	-1000014	14	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\nu}_\mu L^*$	ν_μ)
3.18162814E-03	2	1000016	-16	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\nu}_\tau$	ν_τ b)
3.18162814E-03	2	-1000016	16	# BR($\tilde{\chi}_{30} \rightarrow \tilde{\nu}_\tau^*$	ν_τ)

#

#	PDG	Width	# neutralino4 decays		
#	BR	NDA	ID1	ID2	
2.08250509E-02	2	1000022	23	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{10}$	Z)
1.85725667E-02	2	1000023	23	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{20}$	Z)
0.00000000E+00	2	1000025	23	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{30}$	Z)
2.61809331E-01	2	1000024	-24	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{1+}$	W-)
2.61809331E-01	2	-1000024	24	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{1-}$	W+)
0.00000000E+00	2	1000037	-24	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{2+}$	W-)
0.00000000E+00	2	-1000037	24	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{2-}$	W+)

6.29362490E-02	2	1000022	25	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{10}$	h)
0.00000000E+00	2	1000022	35	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{10}$	H)
0.00000000E+00	2	1000022	36	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{10}$	A)
1.33506859E-01	2	1000023	25	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{20}$	h)
0.00000000E+00	2	1000023	35	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{20}$	H)
0.00000000E+00	2	1000023	36	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{20}$	A)
0.00000000E+00	2	1000025	25	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{30}$	h)
0.00000000E+00	2	1000025	35	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{30}$	H)
0.00000000E+00	2	1000025	36	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{30}$	A)
0.00000000E+00	2	1000024	-37	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{1+}$	H-)
0.00000000E+00	2	-1000024	37	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{1-}$	H+)
0.00000000E+00	2	1000037	-37	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{2+}$	H-)
0.00000000E+00	2	-1000037	37	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\chi}_{2-}$	H+)
0.00000000E+00	2	1000002	-2	# BR($\tilde{\chi}_{40} \rightarrow \tilde{u}_L$	ub)
0.00000000E+00	2	-1000002	2	# BR($\tilde{\chi}_{40} \rightarrow \tilde{u}_L^*$	u)
0.00000000E+00	2	2000002	-2	# BR($\tilde{\chi}_{40} \rightarrow \tilde{u}_R$	ub)
0.00000000E+00	2	-2000002	2	# BR($\tilde{\chi}_{40} \rightarrow \tilde{u}_R^*$	u)
0.00000000E+00	2	1000001	-1	# BR($\tilde{\chi}_{40} \rightarrow \tilde{d}_L$	db)
0.00000000E+00	2	-1000001	1	# BR($\tilde{\chi}_{40} \rightarrow \tilde{d}_L^*$	d)
0.00000000E+00	2	2000001	-1	# BR($\tilde{\chi}_{40} \rightarrow \tilde{d}_R$	db)
0.00000000E+00	2	-2000001	1	# BR($\tilde{\chi}_{40} \rightarrow \tilde{d}_R^*$	d)
0.00000000E+00	2	1000004	-4	# BR($\tilde{\chi}_{40} \rightarrow \tilde{c}_L$	cb)
0.00000000E+00	2	-1000004	4	# BR($\tilde{\chi}_{40} \rightarrow \tilde{c}_L^*$	c)
0.00000000E+00	2	2000004	-4	# BR($\tilde{\chi}_{40} \rightarrow \tilde{c}_R$	cb)
0.00000000E+00	2	-2000004	4	# BR($\tilde{\chi}_{40} \rightarrow \tilde{c}_R^*$	c)
0.00000000E+00	2	1000003	-3	# BR($\tilde{\chi}_{40} \rightarrow \tilde{s}_L$	sb)
0.00000000E+00	2	-1000003	3	# BR($\tilde{\chi}_{40} \rightarrow \tilde{s}_L^*$	s)
0.00000000E+00	2	2000003	-3	# BR($\tilde{\chi}_{40} \rightarrow \tilde{s}_R$	sb)
0.00000000E+00	2	-2000003	3	# BR($\tilde{\chi}_{40} \rightarrow \tilde{s}_R^*$	s)
0.00000000E+00	2	1000006	-6	# BR($\tilde{\chi}_{40} \rightarrow \tilde{t}_1$	tb)
0.00000000E+00	2	-1000006	6	# BR($\tilde{\chi}_{40} \rightarrow \tilde{t}_1^*$	t)
0.00000000E+00	2	2000006	-6	# BR($\tilde{\chi}_{40} \rightarrow \tilde{t}_2$	tb)
0.00000000E+00	2	-2000006	6	# BR($\tilde{\chi}_{40} \rightarrow \tilde{t}_2^*$	t)
0.00000000E+00	2	1000005	-5	# BR($\tilde{\chi}_{40} \rightarrow \tilde{b}_1$	bb)
0.00000000E+00	2	-1000005	5	# BR($\tilde{\chi}_{40} \rightarrow \tilde{b}_1^*$	b)
0.00000000E+00	2	2000005	-5	# BR($\tilde{\chi}_{40} \rightarrow \tilde{b}_2$	bb)
0.00000000E+00	2	-2000005	5	# BR($\tilde{\chi}_{40} \rightarrow \tilde{b}_2^*$	b)
9.78996815E-03	2	1000011	-11	# BR($\tilde{\chi}_{40} \rightarrow \tilde{e}_L-$	e+)
9.78996815E-03	2	-1000011	11	# BR($\tilde{\chi}_{40} \rightarrow \tilde{e}_L+$	e-)
3.59737855E-03	2	2000011	-11	# BR($\tilde{\chi}_{40} \rightarrow \tilde{e}_R-$	e+)
3.59737855E-03	2	-2000011	11	# BR($\tilde{\chi}_{40} \rightarrow \tilde{e}_R+$	e-)

9.78996815E-03	2	1000013	-13	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\mu}_{L-}$	$\mu+$)
9.78996815E-03	2	-1000013	13	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\mu}_{L+}$	$\mu-$)
3.59737855E-03	2	2000013	-13	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\mu}_{R-}$	$\mu+$)
3.59737855E-03	2	-2000013	13	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\mu}_{R+}$	$\mu-$)
2.50391561E-03	2	1000015	-15	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\tau}_{1-}$	$\tau+$)
2.50391561E-03	2	-1000015	15	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\tau}_{1+}$	$\tau-$)
1.59074552E-02	2	2000015	-15	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\tau}_{2-}$	$\tau+$)
1.59074552E-02	2	-2000015	15	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\tau}_{2+}$	$\tau-$)
2.49773159E-02	2	1000012	-12	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\nu}_{eL}$	ν_{eb})
2.49773159E-02	2	-1000012	12	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\nu}_{eL}^*$	ν_e)
2.49773159E-02	2	1000014	-14	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\nu}_{\mu L}$	$\nu_{\mu b}$)
2.49773159E-02	2	-1000014	14	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\nu}_{\mu L}^*$	ν_{μ})
2.51296109E-02	2	1000016	-16	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\nu}_{\tau 1}$	$\nu_{\tau b}$)
2.51296109E-02	2	-1000016	16	# BR($\tilde{\chi}_{40} \rightarrow \tilde{\nu}_{\tau 1}^*$	ν_{τ})

4.4 Some points about the program

Our results for some representative points of the MSSM parameter space have been carefully cross-checked against other existing codes in mSUGRA-type models [in the case of the AMSB and GMSB models, no very detailed comparisons have been made]. In our comparison with the programs **Isajet** and **SPHENO**, when the sparticle and Higgs spectrum, as well as the various input and soft SUSY-breaking parameters are forced to be the same in both codes, we obtain in general a rather good agreement for the partial widths of the main two-body decay modes. We have also verified that the loop and some three-body decays of the top squark agree qualitatively with those included in, respectively, the codes **Isajet** and **SPHENO**⁶.

However, since there are, as is well known, some differences [of the order of a few per cent] between the outputs of the various RGE codes [see Ref. [44] for a discussion], these discrepancies can lead to a completely different phenomenology. Indeed, some decay channels can be either absent or present in some codes when the masses of the decaying and daughter particles are close to each other. For some multibody decays and for the QCD corrections, no comparison has been made since they are absent from these codes.

The program is under rapid development and we plan to make several upgrades in a near future. A brief and non-exhaustive list of points that will be implemented in the next releases of the program includes:

- (i) the finalization of the inclusion of the decays of the top quark, i.e. the implementation of the QCD corrections;
- (ii) the link with the routine **Hmasses** for a more precise and consistent [with the program] calculation of the Higgs boson masses;

⁶We thank Werner Porod for his gracious help in performing these detailed comparisons.

- (iii) the inclusion of additional higher order decay modes, such as the bottom squark three-body decay widths and some three-body decay modes, which can be important in GMSB models;
- (iv) the inclusion of the finite widths of the propagators of the exchanged particles in the multibody decay modes, to make smooth transitions between the multibody and two-body decay modes;
- (v) at some point, the implementation of some important electroweak radiative corrections [in particular for decays involving top and bottom squarks].

As mentioned earlier, a version where the program **SDECAY** is linked not only to the program **SuSpect** but also to the program **HDECAY** for the calculation of the decay widths and branching ratios of the MSSM Higgs bosons is in preparation. It would allow for a complete description of the properties of SUSY particles and MSSM Higgs bosons, prior to their production at colliders.

Finally, a web page devoted to the **SDECAY** program can be found at the http address:

<http://people.web.psi.ch/muehlleitner/SDECAY>

It contains all the information that is needed on the program:

- downloading directly the various files of the program;
- short explanations of the code and how to run it;
- obtaining the complete “users manual” in post-script or PDF form;
- a regularly updated list of important changes/corrected bugs in the code;
- a mailing list to which one can subscribe to be automatically advised about future **SDECAY** updates or eventual corrections.

5. Conclusions

We have presented the Fortran code **SDECAY**, which evaluates the decay widths and branching ratios of the supersymmetric particles in the MSSM. It includes not only all the possible tree-level decays into two-body final states, but also the various three-body modes for charginos, neutralinos, gluinos and top squarks, the four-body decays of the lightest top squark and the loop-induced decays of the lightest top squark, the next-to-lightest neutralino and the gluino. In addition, the QCD corrections to the tree-level two-body decays, which involve strongly interacting particles and the dominant electroweak corrections due to the running of the gauge and fermion Yukawa couplings are incorporated. Furthermore, we have included the decays of the NLSP in GMSB models and the standard and SUSY decay modes of the heavy top quark.

The program uses the **SuSpect** code for the calculation of the spectrum and the various soft SUSY-breaking parameters, but it can be easily linked to any other RGE code. It can be also linked to the program **HDECAY** for the decays of the MSSM Higgs bosons, to

provide a complete picture of the new particles predicted in the MSSM, except for their production properties. The latter are dealt with by the Monte Carlo event generators with which **SDECAY** can be easily linked since, in particular, it generates an output à la SUSY Les Houches Accord. The program is user-friendly, flexible for the choice of options and approximations, and quite fast. It therefore allows for a rather accurate, reliable and efficient study of the phenomenology of the MSSM superparticles, including the possibility of large scans of the parameter space.

The program is under rapid development and will be maintained regularly to include upgrades, improvements and potentially, corrections. Any suggestion, comment or complaint from the potential users will be welcome.

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